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Brown Trout Stocking: An Annotated Bibliography and Literature Review

101-04196/

Brown Trout Stocking: An Annotated Bibliography and Literature Review

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March 2001

This publication should be cited as follows: Lasenby, T. A. and S. J. Kerr. 2001. Brown trout stocking: An annotated bibliography and literature review. Fish and Wildlife Branch, Ontario Ministry of Natural Resources. Peterborough, Ontario. 187 p. + appendices.

Printed in Ontario, Canada
(0.3 k P. R. 01 15 03)
MNR 51488
ISBN 0-7794-0784-9

Copies of this publication are available from:

Fish and Wildlife Branch
Ontario Ministry of Natural Resources
P. O. Box 7000
300 Water Street
Peterborough, Ontario
K9J 8M5

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Cover drawing by Ruth E. Grant, Brockville, Ontario.

Preface

This bibliography and literature review is the sixth in a series of reference documents developed in conjunction with a review of fish stocking policies and guidelines for the Province of Ontario. It has been prepared to summarize information on the current state of knowledge, regarding the stocking of brown trout, in a form which can be readily utilized by Ontario Ministry of Natural Resources (OMNR) field staff and external stocking proponents.

Material cited in this bibliography includes papers published in scientific journals, magazines and periodicals as well as "gray" literature such as file reports from the OMNR field offices. Unpublished literature was obtained by soliciting information (i.e., unpublished data and file reports) from OMNR field biologists from across Ontario. The majority of the published information was obtained from a comprehensive literature search conducted in the OMNR corporate library in Peterborough. Twenty-one major fisheries journals were reviewed as part of this exercise. These included: Aquaculture (1972-1998), California Fish and Game (1971-2000), Copeia (1913-2000), Environmental Biology of Fishes (1976-2000), Fishery Bulletin (1963-2000), Fisheries Management (1975-1984), Journal of Freshwater Ecology (1981-2000), New York Fish and Game Journal (1954-1985), North American Journal of Fisheries Management (1981-2000), Journal of the Fisheries Research Board of Canada/Canadian Journal of Fisheries and Aquatic Sciences (1950-October 2000), Progressive Fish Culturist/North American Journal of Aquaculture (1940-2000), and Transactions of the American Fisheries Society (1929-September 2000). Material was also obtained from other journals such as the Journal of Wildlife Management, Fisheries, Sylva, Journal of Freshwater Fishing, Wisconsin Conservation Bulletin and Canadian Fish Culturist. Searches were also made of other publications including Proceedings of the Annual Meeting of the Southeastern Association of Fish and Wildlife Agencies, Proceedings of the Annual Meeting of the Western Association of Fish and Wildlife Agencies, Transactions of the Annual North American Fish and Wildlife Conference, Transactions of the Annual Midwest Fish and Wildlife Conference, United States Department of the Interior Fisheries Technical Papers, FAO Fisheries Technical Papers and Circulars, and reports published under the Canadian Technical Report Series of Fisheries and Aquatic Sciences. A search of the World Wide Web was conducted so that abstracts from papers presented at Division meetings of the American Fisheries Society as well as the 2000 Annual Meeting could be presented. Finally, some information was acquired through a search of the Fish and Fisheries Worldwide Database (1971-present) and Cambridge Scientific Abstracts via the Internet.

Approximately 470 citations, of which almost 400 include a synopsis or annotation, are included in this document. Many papers are of European and Scandinavian origin and not all were readily accessible. In cases where abstracts were unavailable, pertinent information from the document was extracted to provide a summary of the findings. Finally, in some cases, we were unable to acquire a copy of the document and have simply included the citation for future reference.

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History of Brown Trout Stocking in Ontario

Brown trout (*Salmo trutta*) was originally believed to be two separate species. The Loch Leven trout (formerly *Salmo leveninsis*) originated in Scotland, while the German brown trout (formerly *Salmo fario*), was from Germany. It is now believed that these fish were simply local strains of the same species. Both varieties were introduced into the United States during the 1880s and shortly after became indistinguishable from one another due to mixing in hatcheries (Holcomb 1964).

Records indicate that brown trout were introduced into Ontario in 1913, although it is suspected that private citizens may have planted the species into several waters at an earlier date (MacCrimmon and Marshall 1968). The first confirmed introduction consisted of fingerlings stocked into the Speed River near Hespeler and into several streams in the counties of Simcoe, Norfolk and Perth (MacKay 1957). Trout planted in Perth County were of the German variety (Anonymous 1914). At this time Ontario had no brown trout rearing facilities and the fish were obtained from Pennsylvania (MacCrimmon and Marshall 1968). Other early introductions of brown trout in Ontario were made using parental brood stock from Michigan hatcheries and were of unknown strain (Crossman 1984).

Brown trout were experimental rearing at the Mount Pleasant hatchery resulted in 2,590 fish being planted into Big Clear Lake (Frontenac County), Eagle Lake (Peterborough County), Nepahwin Lake (Sudbury District) and Muskoka Lake (Muskoka District), in 1929 (Anonymous 1930). Several early introductions of the brown trout into Ontario waters are presented in Table 1. During the initial years, retention of a brown trout brood stock was restricted to the Mount Pleasant facility with the provincial fish hatchery at Kenora also providing facilities to handle the fish to the fry stage (Anonymous 1932). By 1949, six hatcheries (Chatsworth, Codrington, Glenora, Ingersoll, Mount Pleasant and Normandale) were involved in some form of brown trout culture (Anonymous 1950).

Table 1. Some early stocking records of brown trout in Ontario waterbodies.

Year	Waterbody (County)	Life stage	Number Stocked	Reference
1913	Speed River (Hespeler)	Unknown	1,000	Anonymous (1914)
1913	Misc. Simcoe area streams (Norfolk)	Unknown	1,000	Anonymous (1914)
1913	Misc. streams (Perth)	Unknown	1,000	Anonymous (1914)
1914	Whiteman's Creeks (Waterloo)	Unknown	800	Anonymous (1915)
1918	Misc. St. Williams area streams (Norfolk)	Unknown	15,000	Anonymous (1919)
1918	Glencoe area pond (Middlesex)	Unknown	10,000	Anonymous (1919)
1929	Big Clear Lake (Frontenac)	Adults	400	Anonymous (1930)
1929	Eagle Lake (Peterborough)	Adults	1,000	Anonymous (1930)
1929	Muskoka Lake (Muskoka)	Adults	800	Anonymous (1930)
1929	Nepahwin (Sudbury)	Adults	390	Anonymous (1930)
1931	Mississippi River (Carleton)	Fingerlings	15,000	Anonymous (1932)
1931	Saugeen River (Grey)	Fingerlings	15,000	Anonymous (1932)
1931	Trout Lake (Kenora)	Fingerlings	15,000	Anonymous (1932)
1931	Charleston Lake (Leeds)	Fingerlings	15,000	Anonymous (1932)
1931	Muskoka River (Muskoka)	Fingerlings	8,000	Anonymous (1932)
1931	Rosseau River (Muskoka)	Fingerlings	8,000	Anonymous (1932)
1931	Maitland River (Perth)	Fingerlings	10,000	Anonymous (1932)

...cont'd

Table 1 (cont'd)

Year	Waterbody (County)	Life Stage	Number Stocked	Reference
1932	Lake Manitou (Manitoulin)	Fingerlings	10,000	Anonymous (1933)
1932	Madawaska River (Renfrew)	Fingerlings	30,000	Anonymous (1933)
1933	Haliburton Lake (Haliburton)	Fingerlings	5,000	Anonymous (1934)
1933	Humber River (Peel)	Fingerlings	10,000	Anonymous (1934)
1933	Catchacoma Lake (Peterborough)	Fingerlings	25,000	Anonymous (1934)
1933	Grand River (Waterloo)	Fingerlings	15,000	Anonymous (1934)
1933	Ganaraska River (Durham)	Yearlings	674	Anonymous (1934)

In 1932, a brown trout stocking policy was endorsed by the Ontario government which allowed planting only in streams where brook trout did not exist and in lake trout lakes without tributary streams (Anonymous 1933).

Between 1913 and 1962, approximately ten million brown trout fry, fingerlings and yearlings were planted into Ontario waters by the provincial government (MacCrimmon and Marshall 1968). Over the course of the last century numerous fish culture stations have been involved in the rearing of brown trout (Table 2). The culture of brown trout ceased in the early 1960s due to disease concerns. It was feared that furunculosis was being passed on to native trout populations (Anonymous 1983). In 1982 the culture of brown trout was revived at Codrington Fish Culture Station and 290,000 eggs were collected from the Ganaraska and Sydenham rivers, reared to the fingerling and yearling stages and returned to those rivers. These hatchery-reared fish were superior to their predecessors in being pathogen-free. The renewal of the stocking program came at the request of southern Ontario anglers in contrast to the attitudes of anglers in the 1960s who felt that the return on hatchery trout was too low to make an impact on the brown trout fishery (MacCrimmon and Marshall 1968). Brown trout stocking in Ontario has continued on an annual basis since 1982 (Anonymous 1982).

Table 2. The propagation of brown trout in Ontario government hatcheries, 1929-2000.

Name	Years of Operation	Known Year(s) of Brown Trout Propagation
Mount Pleasant	1909-1965	1929-49
Kenora	1915-?	1930-1931
Ingersoll	1931-1962	1947-1949*
Glenora	1923-1955	1947-1949*
Chatsworth	1936-present	1947-1949*, 1987-2000
Codrington	1930-1991	1947-1949*, 1982-1991
Harwood	1985-present	1986-1992, 1994-2000
Normandale	1917-present	1947-1949, 1986, 1991-2000
Westport	1950-1985	1961
Ringwood	1980-present	1992-1998
Tarentorus	1956-present	1999
White Lake	1934-present	1971, 1993-2000
Blue Jay Creek	1989-present	1997-2000

*Although it is highly likely that these fish culture stations were rearing brown trout for a longer period of time, no specific documentation could be found.

Currently, the majority of the brown trout are stocked into the waters of the Great Lakes (Table 3).

Table 3. Brown trout stocked in Ontario waters by the Ontario Ministry of Natural Resources in 2000.

Region	MNR/Great Lake District	Number of fish stocked by year
Northeastern	Sault Ste. Marie	8,379
Southcentral	Aurora	27,557
	Aylmer	0
	Bancroft	1,000
	Cambridge	33,447
	Kemptville	9,422
	Midhurst	27,372
	Parry Sound	0
	Pembroke	9,831
	Peterborough	500
Great Lakes	Lake Ontario	167,033
	Lake Superior	0
Total		**284,541**

Brown trout stocking can vary within administrative districts from one year to the next, depending on the purpose of the stocking; Aurora, Parry Sound and Lake Superior were stocked in 1999. No brown trout were stocked into northwestern Ontario in either 1999 or 2000. In 2000, 167,033 yearling brown trout were stocked into the Great Lakes and 117,508 into inland waters. The total number of brown trout planted in 2000 accounted for only 3.0% of the total number of fish stocked from provincial fish culture stations.

Currently, the only brown trout strain in the Provincial hatchery system is of Ganaraska River origin. Brood stock are taken from Lake Ontario and the Ganaraska River. This strain reproduces naturally, although its migrational tendencies are limited. Since 1991, the Normandale Fish Culture Station has been rearing the captive brood stock (Ontario Ministry of Natural Resources 1999).

Synthesis of Selected Literature

This section will attempt to summarize selected stocking-related topics under the following categories:

1. Benefits of stocking brown trout
2. Survival of stocked brown trout
3. Contributions of stocked brown trout to the fishery
4. Factors influencing stocking success
5. Potential impacts of stocked brown trout
6. Best management practices for brown trout stocking
7. Stocking assessment

Benefits of Stocking Brown Trout

Brown trout have often been criticized for their low returns to the angler in comparison to other salmonids such as rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*), however, they are superior as a stocked species in many other aspects (Table 4).

Table 4. Factors which favour the stocking of brown trout over other salmonids.

Factor	Reference(s)
More challenging to anglers (i.e. difficult to catch)	Nielson (1953), Mansell (1966), Johnson (1978), Wisconsin Department of Natural Resources (1980), Crossman (1984), Goodman (1991), Pawson (1991), Heidinger (1993)
Longer contribution to fishery than brook trout	Shetter and Hazzard (1940), Trembley (1943), Thorpe et al. (1947), Cooper (1952), Anonymous (1953), McCaig et al. (1960), Heidinger (1993)
Longer contribution to fishery than rainbow trout	Thorpe et al. (1947), Cooper (1952), Heidingre (1993)
Greater second year contributions to the fishery than brook trout or rainbow trout	Vermont Department of Fish and Wildlife (1993)
Faster growth than brook trout	Trembley (1943), Wales (1946)
Higher percent survival to anglers than brook trout or rainbow trout fingerlings	Wales (1946)
Greater overall survival than brook trout	Johnson (1983)
Can withstand warmer water temperatures than brook and/or rainbow trout and can therefore be stocked into a wider variety of waters	Mansell (1966), Johnson (1978), Dumont and Mongeau (1990), Goodman (1991)

It has been found that the first year yield of stocked brown trout has been lower (in many cases significantly so) than that of both rainbow trout (North 1983, Schumacher 1958) and brook trout

(Hale 1952$_b$, 1954; Trembley 1943). However, Skurdal et al. (1989) found that stocked brown trout can contribute to the angler's catch for up to three years following their release, and, in constrast to both rainbow and brook trout, brown trout often have a greater chance at survival beyond the first year after release (Vermont Department of Fish and Wildlife 1993, Wales 1946). A higher survival rate typically results in greater angling opportunities and ultimately a reduced need for stockings, either in number or in frequency.

Survival of Stocked Brown Trout

Post-stocking survival is usually reported as a percentage of the number of fish originally stocked which are recovered during a finite period of time. Post-stocking survival reported in the literature is presented in Appendix 2 and summarized in Table 5. The emigration of fish between the time of release and recapture can cause difficulties in properly assessing survival rates. This is particularly true in open systems such as rivers and streams. Various techniques have been used to assess survival and will be summarized in a succeeding section. The stocking of brown trout is most prevalent in flowing waters. Generally, survival rates were poorest for brown trout stocked into rivers.

Table 5. A summary of post-stocking survival rates for brown trout reported from various North American and European jurisdictions.

	Reported Survival Rates in Various Waterbodies			
Life Stage Stocked	Creeks/Streams	Lakes	Ponds	Rivers
Fry	14.4-33.0% (N=2)	-	-	-
Fingerlings	7.0-90.0% (N=7)	0.0-44.0%(N=4)	30.0-93.1% (N=3)	1.0-40.1% (N=4)
Yearlings	11.3% (N=1)	-	-	2.0-26.0% (N=4)
Adults	14.0-86.0% (N=2)	-	-	-
Unknown	12.1-12.3%(N=2)	-	-	-

The limited post-stocking survival data available for life stages other than fingerlings, does not allow a thorough comparison between the survival of brown trout in different waterbodies. It is apparent however, that, in streams, the survival of trout is greater with older aged fish. The survival rates of fry can be inconsistent. Kelly-Quinn and Bracken (1989$_a$) determined that mortality rates of stocked trout were the lowest where there occurred the smallest number of wild fry. Wales (1946) believed that there was no significant difference in the survival of various sized brown trout fingerlings. Brynildson et al. (1963) found that survival was low in the presence of predators and large populations of competitors. Brown trout are highly aggressive and large individuals can inhibit the stocking success of subsequent plants (Wisconsin Department of Natural Resources 1980). The performance of hatchery-reared brown trout does not match that of their wild counterparts in terms of survival. Alexander (1985) found that survival of hatchery fish approximates only half that of wild trout, whereas Skaala et al. (1996) determined their survival to be only one-third that of feral brown trout.

Contributions of Stocked Brown Trout to the Fishery

The contributions of brown trout to the fishery are typically assessed through a creel survey of some type. Marking hatchery-reared fish facilitates evaluation by anglers by allowing them to easily distinguish between stocked and native fish. Contributions to the fishery are generally reported as the percentage of fish returned to the angler in proportion to the number stocked. Brown trout have often been reported as difficult to catch and, as such, provide a challenge to many anglers. Contributions of stocked brown trout to recreational fisheries in various inland waters appear in Appendix 3 and are summarized in Table 6.

Table 6. Contributions of stocked brown trout to fisheries in various North American and European jurisdictions.

	Reported Contributions of Stocked Brown Trout to a Fishery			
Life Stage Stocked	Creeks/Streams	Lakes	Reservoirs	Rivers
Fingerlings	0.1% (N=1)	1.3-9.3% (N=4)	<1.0% (N=1)	-
Yearlings	2.8-68.3% (N=7)	32.0% (N=1)	-	8.1% (N=1)
1 and 2 year olds	-	12.1-16.8% (N=2)	-	20.3% (N=1)
Adults/Catchables	0.0-54.8% (N=12)	46.0% (N=1)	42.2% (N=1)	1.0-58.0% (N=19)

The return of fingerlings to the angler is generally poor, while those catchable-sized fish provide higher returns, likely due to the fact that they are eligible for harvest during their first season of release. Brown trout are a difficult species to catch and it is possible that lakes allow for more elusive behaviour than flowing waters. Catchable-sized brown trout appear to contribute the most to the angler's creel when planted into rivers.

The return of planted brown trout to the angler is maximized in areas having the lowest resident populations of trout (Fitch 1977). If stocked fish are concentrated in a few specific areas their presence in the angler's catch can be great. Cooper (1952) discovered that stocked sections of a river attracted three times as many anglers as unstocked sites. In comparison with brook trout and the rainbow trout, the brown trout do not provide as efficient a return to the angler because of the greater degree of difficulty involved in their capture (Wisconsin Department of Natural Resources 1980). It has also been found that catchability of stocked brown trout diminishes over time (North 1983).

Factors Influencing Stocking Success

Stocking success is measured primarily in two ways: post-release survival of the stocked fish and the contribution of the planted fish to the fishery. Various parameters, such as the quality of the recipient water and the stocking methods employed, can impact the welfare of brown trout when entering a waterbody. Biological qualities of the receiving waterbody such as food availability, predator presence and competition with resident fish can influence the success or failure of a stocking project. Traits of the stocked fish such as genetic strain, age, size and health can affect their performance in a new waterbody. All of these factors ultimately dictate the post-stocking success of brown trout (see Table 7).

Table 7. Factors influencing the stocking success of brown trout.

Factor	References
Poor habitat and/or water quality	MacKay (undated, 1957), Anonymous (1930), Nielson (1953), Mason and Wegner (1970), Marshall and Johnson (1971), Pyle and Soldwedel (1973), Klein (1975), McLaren (1979), Helfrich and Kendall (1982), Marshall and Menzel (1984), Raddum et al. (1986), Heggenes (1988), Goodman (1991), L'Abee-Lund and Saegrov (1991), Greenberg (1992), L'Abee-Lund et al. (1992), Barlaup and Åtland (1994), Toivonen et al. (1994), Hesthagen et al. (1995), Johnstone et al. (1995), L'Abee-Lund and Langeland (1995), Barlaup et al. (1996), Goudreau (1998), Ugedal et al. (1998), Jutila et al. (1999), Bettross (2000)
Age/size of fish when stocked	Holloway and Chamberlain (1942), Needham and Slater (1944), Curtis (1951), Hale (1952$_b$), Anonymous (1953, 1954), Hale and Smith (1955), Mullan (1956), Wilde (1956), Preston (1965), Needham (1969), Fitch (1977), O'Grady (1982), Kennedy (1982), Ferguson (1983), Ferguson (1986), Weber (1988), Kelly-Quinn and Bracken (1989$_a$), Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_a$) (1988$_b$), Johnsen and Hesthagen (1990), Naeslund (1990), Taggart and Vehanen (1995)
Genetic strain	Heacox (1937), Miller and Alcorn (1943), Boles (1960), Holcomb (1964), Boles and Borgenson (1966), Mansell (1966), Staley (1966), Larsson et al. (1979), Ryman and Ståhl (1980), O'Grady (1982), Alexander (1985), Barwick and Geddings (1985), Hulbert (1985), Krueger et al. (1986), Krueger and May (1987), Borawa (1988), Barbat-Letterrier et al. (1989), Hofman (1989), Moran et al. (1989), Aass (1990$_b$, 1993), Nihouarn et al. (1990), L'Abee-Lund and Saegrov (1992), Alexander and Nuhfer (1993), Naeslund (1993), L'Abee-Lund and Langeland (1995), Nuhfer (1996), Anonymous (1997, 1998), Fajfer and Belonger (1997), Weiss and Kummer (1999), Wisconsin Bureau of Fisheries Management and Habitat Protection (1999)
Stocking technique: (a) Time of stocking	Nesbit and Kitson (1937), Shetter and Hazzard (1940), Chamberlain (1943), Trembley (1943), Shetter (1944), Anonymous (1953, 1956), Christenson et al. (1954), Barker (1955), Kuehn and Schumacher (1957), Schumacher (1958), Mullan and Tompkins (1959), Brynildson et al. (1963), Boles and Borgenson (1966), Templeton (1971), Strange and Kennedy (1979), Cresswell (1981), Cresswell and Williams (1982), Kennedy (1982), O'Grady (1982, 1983), Aass (1984), Kennedy et al. (1984), Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_a$), Hesthagen and Johnsen (1989$_b$), Hofman (1989), Ahvonen and Ikonen (1993), Naeslund (1993), Maine Fisheries Research and Management Section (2000)
(b) Scatter versus spot stocking	Shetter and Hazzard (1940), Shetter (1944), Cooper (1952), Anonymous (1953), Larsen (1972), Klein (1975), Cresswell and Williams (1982), Cresswell et al. (1982), Marshall and Menzel (1984), Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$), Hofman (1989), Jokikokko (1999), Jonssonn et al. (1999)

...cont'd

Table 7 (cont'd)

Factor	References
(c) Handling, transport and acclimatization	Miller (1958), Hosmer (1980), Nikinmaa et al. (1983), Cresswell and Williams (1983), Luton (1985), Johnsen and Hesthagen (1990), Jonssonn et al. (1999), Barton (2000)
(d) Stocking rates	Cooper (1952), Anonymous (1954), Kelly (1965), Butler (1975), Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_a$, 1988$_b$), Kelly-Quinn and Bracken (1989$_a$), Wahab et al. (1989), Saura et al. (1990), Hesthagen and Johnsen (1992), Vehanen (1995), Rasmussen and Geertz-Hansen (1998), Maine Fisheries Research and Management Section (2000)
(e) Stocking sites	Schuck and Kingsbury (1948), Mason and Wegner (1970), Lorz (1974), Klein (1975), Fitch (1977), Bartel (1988), Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$), Johnsen and Hesthagen (1990), Ahvonen and Ikonen (1993), Fjellheim et al. (1995), Jonsson et al. (1995), Rasmussen and Geertz-Hansen (1998), Maine Fisheries Research and Management Section (2000)
Diet conversion and starvation	Lachner and Raney (1941), Webster and Little (1944), Wales (1946), Boles (1960), Kirkland and Bowling (1966), Brynildson and Kempinger (1973), Cresswell et al. (1982), Garman and Nielsen (1982), Bachman (1984), De Rocha and Mill (1984), Johnsen and Ugedal (1986, 1989, 1990), O'Gorman et al. (1987), Kelly-Quinn and Bracken (1989$_b$), Aass (1990$_a$), Krueger and May (1991), L'Abee-Lund and Saegrov (1991, 1992), L'Abee-Lund et al. (1992), Lucas (1993), Toivonen et al. (1994), Hesthagen et al. (1995), Vehanen (1995), Crisp (1996), L'Abee-Lund and Langeland (1995), Rahkonen and Koski (1997), Pirhonen et al. (1998), Vehanen, Hyvarienen and Huusko (1998)
Fish health and disease	Cooper and Benson (1951), Nicholls (1958), Kernen (1969), Hosmer (1980), Cresswell et al. (1982), Eckert (1982),Anonymous (1983, 1999$_a$), Hulbert (1985), Bouvet and Chacormac (1986), Borawa (1988), DeWald and Wilzbach (1992), Arias et al. (1995), Haunschmid and Kozak (1997), Rahkonen and Koski (1997), Pirhonen et al. (1998)
Intraspecific competition	Needhan and Slater (1944), Mullan (1956), Miller (1958), McLaren (1979), Zalewski et al. (1985), Greenberg (1992)
Interspecific competition	Brynildson et al. (1963), Staley (1966), McDowall (1968), Avery (1978), Kennedy (1982), O'Gorman et al. (1987), Von Rosen (1989), Dumont and Mongeau (1990), McIntosh et al. (1992), Lucas (1993)
Predation	MacKay (undated), Brynildson et al. (1963), Marshall and Johnson (1971), Klein (1975), Cresswell et al. (1982), Greenberg (1992), Hesthagen and Johnsen (1992), Dieperink (1995), Vehanen (1995), Johnsson et al. (1996), Johnsen et al. (1998)

...cont'd

Table 7 (cont'd)

Factor	References
Movements of stocked fish	Cobb (1933), Trembley (1943), Brynildson (1967), Skrochwska (1969), Cresswell and Williams (1979, 1982, 1983, 1984), Scullion and Edwards (1979), Cresswell (1981), Cresswell et al. (1982), Kennedy (1982), Helfrich and Kendall (1983), Nettles et al. (1987), Skurdal et al. (1989), Marconato et al. (1990), Jorgensen and Berg (1991), Naeslund (1992), Johnstone et al. (1995), Vehanen, Devlin and Bettoli (1998), Pirhonen et al. (1998), Hyvarinen and Aspi (1998), Schulz (1999), Weiss and Kummer (1999), Aarestrup et al. (2000)

Habitat and Water Quality – Obviously, conditions of the receiving waterbody can greatly influence the success of stocked brown trout. Brown trout should be stocked in an area where habitat and water chemical parameters are well within their tolerable range. Ideal habitat conditions for stocked brown trout are summarized in Table 8. In flowing waters brown trout prefer rocky substrates to smooth bottoms (Heggenes 1988, Jutila et al. 1999). Coarse gravel and rocks are used by fry as shelter during daylight hours (Heggenes 1988). Brown trout less than four inches in total length favour littoral zones, and these areas should comprise a large portion of the recipient waterbody (Klein 1975). Stocked brown trout have the same habitat requirements as resident populations (Greenberg 1992, L'Abee-Lund and Langeland 1995). Brown trout are highly adaptable and have been known to thrive in waters considered too warm for brook trout (Anonymous 1930, MacKay undated). Highly acidic waters have been found to seriously reduce growth (Barlaup and Åtland 1994, Barlaup et al. 1996). Stocking success has been achieved in large, oligotrophic lakes (Toivonen et al. 1994). Factors such as low oxygen, high levels of sedimentation, unstable water levels and lack of spawning tributaries can have negative effects on brown trout stocking success (Bettross 2000, Goudreau 1998, Marshall and Johnson 1971).

Table 8. General habitat requirements for stocked brown trout.

Parameter	Requirement
Waterbody	• Can thrive in streams, lakes and rivers.
Vegetation	• There should be overhanging and submerged vegetation.
Water depth	• Water should be greater than 15 cm in depth and between 7-58 cm is needed for spawning.
Water velocity	• Waters should have only a small flow, less than 15cm sec^{-1} during the winter.
Water temperature	• Preferred temperatures for brown trout vary from 10-17.6° C. • Spawning temperature varies from 6.7-8.9° C.
Dissolved oxygen	• The optimal range for brown trout is between 7 and 9 mg L^{-1}.
pH	• The optimal range is 6.8-7.8, although brown trout can tolerate 5.0-9.5.

...cont'd

Table 8 (cont'd)

Parameter	Requirement
Substrate	• Coarse gravel is preferred and cover such as boulders, undercut banks and logs is also important.
Total dissolved solids (TDS)	• Growth has been found to be positively correlated with TDS. • Should be <800.0 mg L^{-1} for culture purposes.
Alkalinity	• Growth rate has been found to be higher in alkaline waters. • Should be between 20-200 mg L^{-1} for culture purposes.

Age and Size of Fish Stocked – Generally, the larger the brown trout when stocked the greater its chance of survival. Older fish have been found to produce higher returns to the creel than smaller/younger fish (Curtis 1951, Anonymous 1954, Mullan 1956, Wilde 1956, Kennedy 1982, O'Grady 1982, Weber 1988). Stocking success has been found to be greatest with two and three year old brown trout (Mullan 1956). The stocking of younger brown trout can also be successful when carried out under specific circumstances. Fry and fingerlings will only thrive in an environment which is virtually predator and competitor-free, whereas larger fish are better prepared to deal with predation and competition (Québec Ministère du Loisir, de la Chasse et de la Pêche 1988_a). It was discovered the stocking of fry into a stream barren of other brown trout had a positive impact 16 months following the plant (Ferguson 1983). In some stocking situations, even yearlings will only be successful when the resident fish population is small (Wilde 1956). The size of brown trout at stocking should complement the traits of the recipient waterbody. Younger fish have less of a chance of surviving overwinter than older trout and small fish planted into a waterbody which experiences severe winter conditions will not likely survive (Fitch 1977). Fingerlings planted into large lakes produce trivial returns in contrast to those planted into small lakes, yet the contribution of fingerlings in lakes can still be greater than that in streams (Curtis 1951, Anonymous 1953). The various sizes and ages of brown trout which have been stocked appear in Table 9.

Table 9. Size/age of brown trout stocked in inland waters.

Size/Age	Waterbody	Purpose	Reference
Eyed eggs	Rivers of the Lower Lough Erne Drainage (Ireland)	Supplemental stocking	Taggart and Ferguson (1986)
Fry	All small streams in Germany	Natural rearing conditions for stocking	Trzebiatowski (1993)
	Lakes, rivers and streams in Québec with little/no competition or predation	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988_b)
	Small streams (which are lightly fished)	-	Needham (1969)

...cont'd

Table 9 (cont'd)

Size/Age	Waterbody	Purpose	Reference
Fry (cont'd)	Vantaanjoki River (Finland)	To achieve an ultimate yield of 30 1-year-old trout per 100 m^2	Saura et al. (1990)
Age-0	Nebish Lake (Wisconsin)	Experimental introduction	Brynildson and Kempinger (1973)
Age-0+	Laciktabaecken Brook (Sweden)	Experimental	Naeslund (1990)
Fingerlings	Culverson Creek (West Virginia)	Re-introduction	Preston (1965)
	Eight unnamed streams (Norway)	Experimental	Johnsen and Ugedal (1988)
	Gamble Creek (Michigan)	Experimental: return to the angler	Anonymous (1953)
	Lake Huron	Put-grow-and-take angling	Weber (1988)
	Lakes, rivers and streams in Québec with moderate competition or predation	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988_b)
	Rivers of the Lower Lough Erne Drainage (Ireland)	Supplemental stocking	Taggart and Ferguson (1986)
	Unnamed streams (Poland)	Introduction	Zalewski et al. (1985)
2-inch fingerlings	Small streams (which are lightly fished)	-	Needham (1969)
3-5-inch fingerlings	Streams (which are moderately to heavily fished)	-	Needham (1969)
8-12 month-old fish	River Gudena (Denmark)	Experimental: wild versus hatchery survival	Berg and Jorgensen (1991)
5-7-inches in total length	Mill River (North Carolina)	Experimental angling	Holloway and Chamberlain (1942)
Yearlings	Dusche Creek (Minnesota)	Experimental angling	Schumacher (1954)
	Lake Huron (Michigan)	Put-grow-and-take angling	Weber (1988)

...cont'd

Table 9 (cont'd)

Size/Age	Waterbody	Purpose	Reference
Yearlings (cont'd)	Lakes, rivers and streams in Québec with high competition or predation	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$)
	Sucker River (Minnesota)	Put-grow-and-take angling	Hale (1952$_b$)
Spring yearlings	August Creek (Michigan)	Put-grow-and-take angling	Dexter (1991)
	Brooks and streams (Maine)	Put-grow-and-take angling	Maine Fisheries Research and Management Section (2000)
Fall yearlings	Lakes and ponds (Maine)	Put-grow-and-take angling	Maine Fisheries Research and Management Section (2000)
6-inches and larger	Streams (which are heavily fished)	-	Needham (1969)
6-12-inches total length	Unnamed streams and lakes (New Mexico)	Experimental tag recovery	Barker (1955)
	Unnamed streams (Massachusetts)	Experimental: differential survival	Mullan (1956)
18 cm (minimum)-25 cm (optimal) in length	Finnish lakes	-	Toivonen et al. (1994)
Adults	Split River (Minnesota)	Put-and-take angling	Hale (1952$_b$)
	Unnamed stream (Austria)	Experimental	Weiss and Schmutz (1999$_a$)
Catchables	Deerfield River (Massachusetts)	Experimental angling	Swartz (1950)
	Lågen and Otta Rivers (Norway)	Experimental	Skurdal et al. (1989)
	Lower Sardine Lake (California)	Experimental: returns of domestic versus wild	Boles (1960)
	State of North Carolina (inclusive)	-	Louder (1969)

Genetic Strain – Genetic traits are one of the most important factors to consider when choosing a brown trout stock for planting. In general, wild strains have been found to be superior in growth and survival to domesticated strains (Alexander 1985, O'Grady 1982). However, domestic strains of brown trout may occasionally show higher levels of growth than feral strains for short periods of time (Nihouarn et al. 1990). Domesticated strains may be favoured over the related wild strain for their higher contribution to the angler (Boles 1960). Native stocks have been found to have superior repopulation abilities when compared to domesticated stocks (Moran et al. 1989). The Wisconsin Bureau of Fisheries Management and Habitat Protection (1999) has determined that native strains give higher yields than those of foreign origin. Several experiments have been conducted to determine which specific strains are of highest quality. In California, eastern strains were found to return 1.5-2.0 times as many fish to the angler as California strains during their first season in the waterbody (Boles 1960). In Norway, the Hunder strain had the highest growth rate and gave the best return to the angler (Aass 1993). The Rome strain has been found to produce a much greater return than the Catskill strain, and has been especially bred for resistance to furunculosis (Hofman 1989, Hulbert 1985). In other studies (e.g., Nuhfer 1996), however, little difference has been found between the performance of various strains of brown trout.

Stocking Technique – The methods employed during stocking can dictate the success of the brown trout in a new waterbody. Technique involves the time of stocking, the stocking rate, handling and transportation practices, release techniques, and the choice of stocking site.

Time of Stocking – The survival of stocked brown trout can vary significantly with the season in which they were planted. Many studies demonstrate that stocking in the spring will give a much higher return to the angler than stocking during the fall prior to the fishing season (Nesbit and Kitson 1937, Chamberlain 1943, Anonymous 1953, Christenson et al. 1954, Barker 1955, Mullan and Tompkins 1959, Boles and Borgenson 1966, Strange and Kennedy 1979, Kennedy 1982, O'Grady 1982, Ahvonen and Ikonen 1993). In one experiment Kuehn and Schumacher (1957) found that 67% of fall stocked brown trout died prior to the beginning of the angling season. Conversely, there have been studies conducted which demonstrate a greater survival and return to the creel of fall stocked fish than summer- and spring-stocked fish (Trembley 1943, Schumacher 1958, Kennedy et al. 1984). In Ontario it is recommended that brown trout be stocked in the spring (Ontario Ministry of Natural Resources 1981).

Stocking Frequency – There is little mention of brown trout stocking frequency in the literature. If a waterbody is stocked annually, the size of the fish planted subsequent to the first stocking should not be of such small size that the fish become prey to those brown trout stocked the previous year. For any stocking endeavour it is recommended that stocking occur for at least two consecutive years, to account for any environment-related effects on stocking success (Québec Ministère du Loisir, de la Chasse et de la Pêche 1988$_b$).

Handling, Transport and Acclimatization – Acclimatization methods have proved profitable in a few cases where there occurred an increase in the number of fish recaptured (Cresswell and Williams 1983, Jonssonn et al. 1999). Crowding during transportation and excessive handling have been found to have negative effects on the post-stocking survival of brown trout (Hosmer 1980, Luton 1985). The distance between the hatchery and the recipient waterbody is instrumental in dictating the well-being of the trout. Johnsen and Hesthagen (1990) discovered that the closer the receiving waterbody, the higher the fish recapture rate. The health of the fish is also pertinent as diseased or parasitized brown trout are more susceptible to negative effects caused by handling stress (Hosmer 1980).

Stocking Rates – Reported brown trout stocking rates appear in Table 10. Stocking rates vary widely and, as such, it is difficult to compare different stocking projects. The density of fish stocked generally depends on the nature of the waterbody and the presence/absence of other fish species. It is suggested that the density of fish stocked be decreased when dealing with increasing numbers of predators (Québec Ministère du Loisir, de la Chasse et de la Pêche 1988$_b$). In other instances there was no relationship between the employed brown trout stocking rate and the catch rate (Anonymous 1954). When a waterbody is already at carrying capacity a change in the fish stocking rate will not likely affect the yield (Kelly-Quinn and Bracken 1989$_a$). In waters which have an unutilized niche, survival rates can increase with stocking density, as can recapture rates (Butler 1975, Hesthagen and Johnsen 1992, Vehanen 1995). The stocking rate should be carefully adjusted to suit the traits of the recipient waterbody.

Table 10. Brown trout stocking rates reported for various projects.

Waterbody	Age/size	Rate(s)	Purpose	Reference
Chattahoochee River (Georgia)	Unknown	50,000, 100,000 and 150,000 in a 27 km section	Experimental	Biagi and Martin (1992)
Clear Creek (Wyoming)	8-inches	233/mile	Supplemental stocking	Anonymous (1954)
Denmark streams	Fry ½-yearlings Yearlings Smolts Older	Up to 200 fish/100 m^2 Up to 50 fish/100 m^2 Up to 20 fish/100 m^2 Up to 10 fish/100 m^2 (for stretches 6-7 m wide) Up to 5 fish/100 m^2	-	Rasmussen and Geertz-Hansen (1998)
Maine lakes and ponds	Fall yearlings	1/acre	-	Maine Fisheries Research and Management Section (2000)
Four small lakes (Norway)	Yearlings	67/ha - 250/ha	Experimental: Survival rates and stocking density	Hesthagen and Johnsen (1992)
Owendoher Stream (Ireland)	Fry	1.67-5.71 m^{-2}	To achieve combined (wild + domestic) density of 3-7 fry m^{-2}	Kelly-Quinn and Bracken (1989$_a$)
Pigeon River (Michigan)	Legal	Up to 431/mile	Experimental	Cooper (1952)

...cont'd

Table 10 (cont'd)

Waterbody	Age/size	Rate(s)	Purpose	Reference
Québec lakes, rivers and streams with little/no competition or predation	Fry	• 1,500/ha • 450/m (width) x km (max. 9,000/km)	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$)
	Fingerlings	• 300/ha • 90/m x km (max. 1,800/km)		
Québec lakes, rivers and streams with moderate competition or predation	Fingerlings	• 200/ha • 60/m (width) x km (max. 1,200/km)	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$)
	Yearlings	• 100/ha • 30/m x km (max. 600/km)		
Québec lakes, rivers and streams with high competition or predation	Yearlings	• 50/ha • 15/m (width) x km (max. 300/km)	-	Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$)
Vantaanjoki River (Finland)	Alevin	300-700 per 100 m^2	To achieve a yield of 30 1-yr-olds per 100 m^2	Saura et al. (1990)

Scatter Versus Spot Stocking – When releasing brown trout there is always the option of depositing the entire allotment in one area, which may be more economically feasible, or distributing the fish over a large portion of the waterbody. There is no single conclusive approach regarding this aspect of the stocking process. Many studies have shown that neither method has an advantage over the other (Shetter and Hazzard 1940, Shetter 1944, Cooper 1952, Anonymous 1953, Marshall and Menzel 1984). Other researchers, meanwhile, have discovered large discrepancies in the numbers of fish recovered from a spot planting as opposed to a scatter planting project. Cresswell and Williams (1982), Cresswell et al. (1982) and Hofman (1989) observed that spot plantings resulted in increased recovery and survival of brown trout. On the contrary, Klein (1975) and the Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$) discovered that scatter plantings are much more advantageous. It is likely that each situation calls for discretion and that neither method is persistently superior. Both the scatter and spot planting methods have proven satisfactory on small rivers and streams (Jokikokko 1999).

Stocking Site – Stocking location can greatly influence the performance of brown trout. Lorz (1974) found a survival rate of 48.0% for those brown trout age-0 to 1 planted in favourable brown trout habitat, while only 19.6% of those placed in unsuitable habitat survived. Klein (1975) recommended that fingerlings, less than four inches in total length, be planted in the littoral zones of a waterbody. Trout should be stocked in an area where wild populations, if present, are least abundant.

Diet Conversion and Starvation – The majority of hatchery-raised brown trout are initially fed an artificial diet and must learn to adjust to natural foods following stocking.

Johnsen and Ugedal (1986) found that, although fish begin to feed shortly after release, it may take up to a week for the trout to learn which items are edible in the wild. During this learning process the stocked trout will likely consume less than their wild counterparts, perhaps decreasing their condition factor (O'Grady 1983, Johnsen and Ugedal 1989, L'Abee-Lund and Langeland 1995). Another study has demonstrated that brown trout do not begin feeding immediately and may even go for weeks without nutritional input (Cresswell et al. 1982). Between one to six weeks following stocking there is little difference between the diet of hatchery and wild brown trout (Cresswell et al. 1982; O'Grady 1983; Johnsen and Ugedal 1986, 1989, 1990; L'Abee-Lund and Langeland 1995). Food items commonly consumed by stocked brown trout are presented in Table 11.

Table 11. Food items of stocked brown trout.

Food Item	Reference(s)
Aquatic and Terrestrial Insects	Lachner and Raney (1941), Webster and Little (1944), Boles (1960), De Rocha and Mill (1984), Johnsen and Ugedal (1989), Kelly-Quinn and Bracken (1989_b), Lucas (1993), Hesthagen et al. (1995)
Arachnids	Lachner and Raney (1941), Webster and Little (1944)
Earthworms	Lachner and Raney (1941), Webster and Little (1944)
Fish:	
Arctic Charr	Aass (1990_a), L'Abee-Lund et al. (1992) Damsgaard and Langeland (1994), Damsgaard (1995)
Torrent Sucker	Garman and Nielsen (1982), Krueger and May (1991)
Vendace	Niva (1999_b), Rahkonen and Koski (1997), Toivonen et al. (1994), Vehanen (1995), Vehanen, Hyvarienen and Huusko (1998)
Whitefish	Rahkonen and Koski (1997), Vehanen (1995)
Perch species	Anonymous (undated_a), De Rocha and Mill (1984), Niva (1999_b)
Sticklebacks (3- and 9-spine)	L'Abee-Lund and Saegrov (1992), Niva (1999_b), Rahkonen and Koski (1997)
Brook trout	Taylor et al. (1984)
Golden trout	Taylor et al. (1984)
Cutthroat trout	Taylor et al. (1984)
Galaxid species	Anonymous (undated_a)
Threadfin Shad	Kirkland and Bowling (1966)
Alewife	O'Gorman et al. (1983)
Trout cod	Anonymous (undated_a)

...cont'd

Table 11 (cont'd)

Food item	Reference(s)
Rainbow Smelt	O'Gorman et al. (1983)
Other	Webster and Little (1944), Brynildson and Kempinger (1973), Lucas (1993), L'Abee-Lund and Langeland (1995)
Zooplankton	Brynildson and Kempinger (1973), Wales (1946), O'Gorman et al. (1987), Kelly-Quinn and Bracken (1989_b), L'Abee-Lund et al. (1992), Hesthagen et al. (1995)
Plant material, sow bugs and gravel	Webster and Little (1944)

Fish Health and Disease – It is important for fish to be as healthy as possible to maximize their survival potential. Many hatcheries have selectively bred strains of brown trout to be resistant to diseases such as furunculosis and whirling disease (Hulbert 1985, Anonymous 1999_a). Haunschmid and Kozak (1997) found that only one half of the stocked brown trout, from a spring stocking, infested with *Gyrodactylus truttae* survived to the fall. Many diseases are easily transmitted from one individual to another. Rahkonen and Koski (1997) discovered that after only three years in a lake all of the stocked brown trout were infested with larval nematodes. Nicholls (1958) discovered that condition of stocked brown trout decreased with age and was always lower than that of resident trout. This inequality may be due to the circumstances under which hatchery fish were reared (Arias et al. 1995).

Intraspecific Competition – The degree of competition between resident and introduced fish can be severe enough to inhibit the survival of the stocked brown trout. The territoriality of the feral population can prevent stocked fish from acquiring favoured space and thus impede their ability to obtain quality resources (Needham and Slater 1944, Miller 1958). Planting brown trout into an area already occupied with a significant number of wild fish is of little value. Miller (1956) has hypothesized that a large number of stocked fish die as an indirect result of competition and believed that the amount of energy consumed in competing for resources is so great that fish die of starvation or stress-induced acidosis.

Interspecific Competition – The brown trout has many competitors, however, it is typically the victor of most competitive encounters. The brown trout has been found to be a highly successful competitor with both warm and coldwater species (Brynildson et al. 1963, Staley 1966, Kennedy 1982, Von Rosen 1989). Documented competitors of brown trout appear in Table 12.

Table 12. Interspecific competitors of stocked brown trout.

Fish Species	Reference(s)
Alewife	O'Gorman et al. (1987)
Brook trout	MacKay (undated), Buss and McCreary (1960), Brynildson et al. (1963), Crossman (1984), Goodman (1991), Krueger and May (1991), DeWald and Wilzbach (1992)

...cont'd

Table 12 (cont'd)

Fish Species	Reference(s)
Common river galaxias	McDowall (1968), McIntosh et al. (1992)
Rainbow trout	Kennedy (1982)
Miscellaneous forage fish	Avery (1978)

Predation – Although brown trout appear to be highly voracious creatures they are also susceptible to predators (see Table 13). During the culture process, fish are protected from predators and therefore have little experience with these encounters. Many hatchery-reared trout may have a prominent silvery appearance for a period of up to 2 months following stocking thereby increasing their visibility to predators (Cresswell et al. 1982, Kennedy 1982). Stocking techniques such as spot planting can greatly increase vulnerability to predators if fish do not disperse immediately (Klein 1975).

Table 13. Predators of stocked brown trout.

Predator	Reference(s)
Brook trout	Marshall and Johnson (1971)
Brown trout	MacKay (undated), Brynildson et al. (1963)
Cormorants	Dieperink (1995)
Northern pike	Johnson (1971), Greenberg (1992), Hesthagen and Johnsen (1992), Marshall and Vehanen (1995)
Perch	Marshall and Johnson (1971)
Walleye	Marshall and Johnson (1971), Johnson et al. (1998)

Post-Stocking Movements – The movements of brown trout following stocking vary depending upon the waterbody into which they are released. Movement in closed systems such as lakes is generally restricted, while streams and rivers allow a wide range of travel. Cresswell et al. (1982) have found that dispersion of stocked brown trout is limited in deep, slow water in contrast to waters which are shallow and fast-flowing. The extent of movement between wild and introduced brown trout may also vary. Wild trout have been found to have a greater upstream movement than domestic brown trout, while the downstream movement of planted trout is more pronounced (Jorgensen and Berg 1991). Schulz (1999) found no difference in the movements between wild and hatchery-reared brown trout. Planted trout often tend to remain close to their stocking site, typically moving no more than one kilometer distance away (Cobb 1933; Trembley 1943; Brynildson 1967; Cresswell 1981; Cresswell and Williams 1979, 1982, 1983, 1984; Skurdal et al. 1989; Marconata et al. 1990; Vehanen, Hyvarinen and Aspi 1998). Conversely, Kennedy (1982) states that stocked brown trout have been known to move up to 100 km from their stocking site and this may result in a reduction of these fish returned to the fishery. The limited movements of introduced brown trout in flowing waters occur in both the upstream and downstream directions. Naeslund (1992) discovered a gradual downstream dispersion of fish from the stocking point and Scullion and Edwards (1979) observed widespread downstream movement. Those brown trout stocked at the lowest end of a tailwater demonstrated continual upstream movement (Devlin and Bettoli 1998). In comparison to the rainbow and brook trout, brown trout were found to travel an average of 90 m upstream after release in contrast to the downstream movements of the other species (Helfrich and Kendall 1983).

Potential Impacts of Stocked Brown Trout

The introduction of brown trout into a waterbody having an established population or in a waterbody having an unutilized niche can have deleterious effects on the native fauna (Table 14).

Table 14. Potential impacts of brown trout stocking.

Potential impact	Reference(s)
Predation on resident species	Brynildson et al. (1963), Staley (1966), Garman and Nielsen (1982), Aass (1984), Wahab et al. (1989), Krueger and May (1991), Townsend and Crowl (1991), L'Abee-Lund and Saegrov (1992), McIntosh et al. (1992), Stenson and Svensson (1994), Kerr and Grant (2000)
Competition/displacement of other fish	Anonymous (undated$_a$), MacKay (undated), Mansell (1966), Burrough and Kennedy (1978$_a$), Garman and Nielsen (1982), Borawa (1988), Welcomme (1988), Dexter (1991), Goodman (1991), DeWald and Wilzbach (1992), McIntosh et al. (1992), Vermont Department of Fish and Wildlife (1993), Ault and White (1994), Damsgaard and Langeland (1994), Cortes (1996), Weiss and Schmutz (1999$_b$), Brooks (2000), Kerr and Grant (2000)
Hybridization	Taggart and Ferguson (1986), Barbat-Leterrier et al. (1989), Budhina and Ocvirk (1990), Hauser et al. (1991), Arias et al. (1993), Martinez et al. (1993), Largiader and Scholl (1995), Skaala et al. (1996), Garcia-Marin et al. (1999), Hansen et al. (2000), Kerr and Grant (2000)
Disease transmission	Anonymous (1982, 1983, 1999$_a$), Hulbert (1985), DeWald and Wilzbach (1992), Kerr and Grant (2000)

As predators, brown trout can greatly impact forage fish populations and may even be beneficial in controlling stunted arctic charr populations (Aass 1984). The size of prey a brown trout is able to consume increases as the trout grows (L'Abee-Lund and Saegrov 1992). Brown trout are also cannibalistic and for this reason stocking small fingerlings in the presence of older brown trout is ineffectual (Brynildson et al. 1963). The species diversity and population numbers of invertebrates such as crustaceans and aquatic insects can be altered through predation by brown trout (Wahab et al. 1989, Stenson and Svensson 1994).

Their wide adaptability allows brown trout to be an excellent competitior and they may prevail at the expense of an established fish population. The introduction of hatchery-reared brown trout on top of a native population will likely negatively impact the wild inhabitants. Studies have demonstrated that natural recruitment can be suppressed by large numbers of stocked trout and that resident trout which are age-II are primarily affected (Cortes 1996, Dexter 1991). However, Weiss and Schmutz (1999$_b$) found that stocking had no detrimental effects on native brown trout stocks. Brown trout have been known to impact brook trout populations (Brynildson et al. 1963, Staley 1966). There is little doubt that brown trout will displace brook trout when introduced into brook trout waters. DeWald and Wilzbach (1992) found that the presence of brown trout in a stream caused brook trout to shift microhabitats and alter their vertical distribution. There have been many incidences where the introduction of brown trout has preceded the disappearance of native brook trout (Mansell 1966, Goodman 1991, Vermont Department of Fish and Wildlife 1993). In Australia and New Zealand, the brown trout has been associated with the displacement of numerous galaxid species (Anonymous undated$_a$, Welcomme 1988, McIntosh et al. 1992, Ault and White 1994). Other species such as Gila trout, perch and arctic charr have also been found to suffer in the presence of brown trout (Burrough and Kennedy 1978$_a$, Damsgaard and Langeland 1994, Brooks 2000).

Barbat-Leterrier et al. (1989) have found that there were no reproductive barriers between wild and hatchery-reared brown trout. The introgression of alleles from hatchery-reared brown trout can often be detrimental to the native population by introducing foreign alleles into the population. It has been found that the waterbody type generally dictates the impact of domesticated genes on the wild population. Native brown trout populations in high-flow waters typically experience less genetic introgression with their domestic counterparts than do fish in in low-flow waterbodies such as lakes (Arias et al. 1993, Martinez et al. 1993). Taggart and Ferguson (1986) found a range of 19-91% in the rates of genetic introgression between rivers in northern Ireland. In order to minimize the impact of possibly deleterious brown trout genes, Garcia-Marin et al. (1999) have determined that the planting of brown trout in the "most-fished" areas will greatly reduce the genetic impact of introduced trout. Although the brown trout has been known to hybridize with other species (Budhina and Ocvirk 1990, Largiader and Scholl 1995), this does not appear to be a major problem in North America.

Brown trout are known for carrying disease and transmitting parasites to other fish. In the 1960s Ontario discontinued brown trout stocking due to suspicions that the trout were infecting native fish populations with furunculosis (Anonymous 1983). Brown trout can carry whirling disease and easily contaminate others while themselves remaining relatively unaffected (Anonymous 1999$_a$). Many hatcheries have developed strains of brown trout which are resistant to specific infections. The Rome strain, extensively used in the United States, was bred to be resistant to furunculosis (Hulbert 1985).

Best Management Practices for Stocking Brown Trout

Based on the information reviewed, several recommendations are offered when stocking brown trout in Ontario waters.

> **Stocking Objective** – Each brown trout stocking project should have a clearly defined purpose. The primary goal must be known in order to properly assess the degree of success of the stocking endeavour. Objectives should include quantitative success with regards to contribution to a fishery or ability of the trout to survive for various lengths of time. A stocking objective will determine the stocking method, as well as the nature of the fish to be used, that will provide the greatest level of success.
>
> **Supplemental Stocking** – Supplemental stocking of brown trout should generally be discouraged. There may be instances where this practice can be beneficial, such as in the case of put-and-take fisheries, where stocks are depleted rapidly and natural reproduction is limited.

Waterbody Suitability –Brown trout can be stocked into flowing waters such as streams and rivers as well as lakes and ponds. Brown trout can adjust to a wide variety of conditions, yet their preferred water temperature range is between 7 and 19° C. The waterbody should include a diversity of cover and the average oxygen concentration should range between 7 and 9 mg L^{-1}.

Strain of Fish – When brown trout are stocked for rehabilitative purposes wild strains should be utilized. The use of localized stocks will minimize the chance of introducing unfavourable alleles into a population. When the stocking objective is to provide fishing opportunities, domestic or semi-domestic strains can be used as they may be more easily caught by anglers. The origin of the strain employed should be compatible with the characteristics of the recipient waterbody and the stocking objective.

Disease Considerations – Brown trout have a history of being carriers of disease and wild individuals used as broodstock, as well as those fish leaving the hatchery, should be tested for parasites and fungal infections (specifically furunculosis). When possible, hatchery strains which have been bred for resistance to certain diseases should be utilized. Only disease-free fish should be stocked in Ontario waters.

Age/Size of Fish Stocked – When choosing the size or age of trout to be stocked it is important that the stocking objective be clear. Certain life-stages of fish are more suitable for some stocking endeavours than others. Typically, the larger the fish the greater are its chances of survival. With brown trout in Ontario, high return to the angler is characteristically a principal stocking objective and the stocking of yearlings or sub-adults is preferred over that of eggs, fry or fingerlings.

Marking – There exist numerous methods that can be used to distinguish planted fish from resident fish. That method which is utilized should be chosen in relation to the estimated time that will pass between stocking and recovery. External tags can be lost or shed, making planted trout indistinguishable from their wild counterparts. Tag retention may be greater in larger fish. Implanted coded wire tags and elastomer tags have a high retention rate, however, if more than one is inlayed they should not be done close together. Dye injections can be performed on fish as small as 2.5 inches and when concentrated pigment is used in the jaw area it can last for up to nine months. Fluorescent pigment spray can last up to twenty months. Fin clipping is a simple procedure which requies very little training to perform, however, fin regeneration can be a problem.

Time of Stocking – In Ontario it is highly recommended that brown trout be stocked as spring yearlings as opposed to fall fingerlings. There may be instances, i.e., in waters with abundant forage and few competitive species, where fall fingerlings could be used effectively.

Stocking Frequency – For introductions, brown trout should be stocked for at least two consecutive years to account for any environment-related factors which may impact stocking success. For put-grow-and-take purposes, stocking is probably best done on an alternate year basis. For put-and-take objectives, annual stocking may be required.

Release Sites – The site at which brown trout are planted should relate to their preferred habitat at the life-stage at which they are being stocked. In lakes brown trout should be distributed along the shoreline. When stocked into flowing waters young-of-the-year trout favour areas that are between one and five meters from the bank, where the water is 15-40 cm deep. The bottom should contain a variety of substrate types. Muddy substrates should be avoided. Yearlings should be planted in shallow areas with low flow, not pools, near the centre of the stream or river. Shelter should be nearby and consist of large rocks or branchs,and undercut banks. Adults prefer slower currents, in areas near streambeds. They should be placed in pools which afford a rocky substrate and an abundance of cover.

Stocking Technique – There is no clear concensus on the superiority of either spot planting or scatter stocking. It does appear however, in certain cases one may be more suitable than the other. For example spot stocking can increase the overall return of stocked fish, while scatter stocking may benefit a larger number of anglers over a longer period of time.

Stocking Assessment

In Ontario post-stocking evaluation is designed to complement the waterbody that is being assessed. In many instances creel studies (i.e., CREESYS) are appropriate when a large survey area is being dealt with. In lakes, survival can be difficult to quantify and an extensive creel census may be the core method of recovery. Volunteer angler reports can provide additional information. In waters where brown trout are known to show very little movement, localized trapping may be an option at the original stocking sites. Netting techniques such as spring littoral index netting (SLIN) or nearshore community index netting (NSCIN) are also legitimate methods of evaluation which are suitable in lakes.

Electrofishing is a common option when conducted along sections of a stream or river. The extent to which a section is electrofished must be carefully monitored since excessive elctrofishing can cause an increase in fish mortality rates.

Both electrofishing and angler surveys, along with other methods of evaluation, are utilized extensively in jurisdictions outside of Ontario. In certain cases placing a trap spanning the width of a river downstream from the stocking site may be suitable for assessment and in some situations the outlet of the stream may be covered in order to capture migrating fish. The emigration of fish between the time of release and recapture can be a problem in some waters.

Long-term effects of brown trout stocking on local populations and the extent to which hatcher-reared fish are recruiting can be assessed using electrophoretic analysis and by identifying genetically tagged hatchery fish. This method will determine the extent of introgression between introduced and feral brown trout populations.

Annotated Bibliography

AARESTRUP, K., C. NIELSEN and S. S. MADSEN. 2000. Relationship between gill Na$^+$,K$^+$-ATPase activity and downstream movement in domesticated and first-generation offspring of wild anadromous brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences 57 : 2086-2095.

The relationship between smolt status and downstream movement following release was investigated in two stocks of hatchery-reared anadromous brown trout (*Salmo trutta*). Yearlings from a domesticated stock (DS) and first-generation offspring (F$_1$) of wild anadromous trout were held under identical conditions from August 1997 until the following spring, where they developed smolt characteristics as judged from increasing gill Na$^+$,K$^+$-ATPase activity. Presmolts (low Na$^+$,K$^+$-ATPase activity), smolts (high Na$^+$,K$^+$-ATPase activity) and desmolts (regressed Na$^+$,K$^+$-ATPase activity) were released on three occasions into the River Salten. Using both dye-marked and radio-tagged fish, downstream movement was monitored by either trapping 3 km downstream (dye-marked fish) or radio-tracking on a daily basis. The experiments showed a positive correlation between smolt status (gill Na$^+$,K$^+$-ATPase activity) and downstream movement. Gill Na$^+$,K$^+$-ATPase activity may therefore be used as an indicator of migratory readiness in brown trout. F$_1$ and DS trout had the highest migration frequency when released as presmolts and smolts, respectively. Despite smaller size, F$_1$ trout had similar or better survival than DS trout after release. Our data suggest that initiation of downstream movement is influenced by an interaction between the previous physiological development of the fish and a discrete level of water discharge or water temperature.

AASS, P. 1978. Age, growth, stocking and yield of brown trout in River Hallingdalselva at Gol, east Norway. Terskelprosjeket Informasjon 7. Norges Vassdrags-og Energiverk. Oslo, Norway.

AASS, P. 1982. Fjord stocking of non-anadromous brown trout (*Salmo trutta*). International Council for the Exploration of the Sea, Committee Meeting, 1982. 33 p.

AASS, P. 1984. Brown trout stocking in Norway. European Inland Fisheries Advisory Committee Technical Paper 42 (Supplement 1) : 123-128.

The brown trout populations of Norway, especially in the high-lying forest and mountain regions are mainly the result of introductions which go back to the Stone Age and have continued to the present day. As a consequence of the rediscovery of artificial propagation, the Government Inspectorate of Salmon and Inland Fisheries was established in 1855, and introductions and stocking became more organized.

About 3 million brown trout are now released yearly, of which fry and autumn fingerlings comprise the major part. About two-thirds of the total number are stocked into hydroelectric reservoirs. The released fish are meant to supplement the natural recruitment, and the stocking density accordingly varies with the local conditions. Ten fingerlings to one hectare is a stocking rate often used.

To explore the effects of stocking, experiments now in progress include 2.5 million fin-clipped or tagged young. The work has mainly taken place in hydroelectric reservoirs with severe living conditions.

After some years of stocking with fingerlings, the proportion of released fish in the catches normally varies between 30% and 50% but extremes of 5% and 75% are recorded. On the basis of total catches and assuming a total rate of exploitation of 75%, it is estimated that in most cases less than 10% of the stocked juveniles survive to catchable size. The number may be as high as 60% in lakes where low natural recruitment and high food production are combined. Increasing the size of the stocked fish will also increase efficiency. Depending on local conditions, one two-summer old juvenile is equivalent to 4-12 autumn fingerlings. In sparsely populated lakes this ratio may be smaller, in reservoirs with predators higher. Releases of fish of catchable sizes will normally give a return of 40-60%, depending on fishing intensity.

Stocking in spring is more efficient than in autumn and so is stocking directly into the reservoirs compared to release in tributaries. The use of fish-eating trout strains in reservoirs crowded with small pelagic fish may give rise to fast-growing individuals, attaining a maximum weight of 15 kg. Such strains are often used in the control of dwarfed char populations. Good returns are also achieved by releasing two-year old predatory trout into fjord systems without prior adjustment of the fish to brackish water.

At present prices, the value of fish flesh recaptured rarely exceeds the cost of stocking. Only the set of big predatory trout or fry and fingerlings in sparsely populated lakes may be directly profitable. However, good fishing is in many places a basis for the tourist industry. Income by hiring out fishing rights or sale of licenses may surpass the purchase sum of the stocked fish. Furthermore, the accommodation of anglers will contribute to making stocking profitable.

AASS, P. 1990$_a$. Management of arctic charr (*Salvelinus alpinus*) and brown trout (*Salmo trutta*) fisheries in Lake Tunhovdfjord, a Norwegian hydroelectric reservoir. p. 382-389. *In* W. L. T. van Densen, B. Steinmetz and R. H. Hughes [eds.]. Management of Freshwater Fisheries. Proceedings of a Symposium by European Inland Fisheries Advisory Committee, 31 May-3 June, 1988, Göteborg, Sweden.

Fishery investigations in Lake Tunhovdfjord commenced in 1917, two years before impoundment. Between 1919 and 1920 the water level rose and the area of the lake increased from 1.425 to 2,535 ha. In the early years the emphasis of the investigations was on the study of food conditions for fish. Later, interest centered on year-class fluctuations, recruitment and migrations, growth rates and yields, and fisheries *per se*. Originally brown trout were the only fish present, but charr and minnows were introduced. Charr is now the most important species, consisting of 90% of the total catch with annual average yields of some 2.7kg/ha. Between 47,000 and 158,000 individuals are landed each year, of which approximately 82% are caught in winter by angling through the ice. The total number of visits by anglers varies from 5,000-6,000 days visits during the winter fishing season, which is high by Norwegian standards. There is a close relationship between hydrology, charr recruitment, migration and yield.

A combined effect of impoundment and the introduction of charr was a change in the diet of the trout, from one in which benthic organisms were predominant to one in which small charr were predominant. After this the maximum weight of trout increased from 3 to 16 kg. The trout population is largely maintained by natural spawning, but there is some stocking with hatchery-reared juveniles of the local strain. Some 28,500 summerlings are released annually and about one third of the total trout catch derives from fish that have been stocked. In all, 790,000 juveniles have been tagged or fincut. Trout fishing is regulated as to time of year, place of fishing, gear permitted and the size of fish that may be taken, but there are few restrictions on charr fishing.

AASS, P. 1990$_b$. Management conflict arising from stocking brown trout (*Salmo trutta*) in Oslofjord, Norway. p. 390-395. *In* W. L. T. van Densen, B. Steinmetz and R. H. Hughes [eds.]. Management of Freshwater Fisheries. Proceedings of a Symposium by EIFAC, 31 May-3 June, 1988, Göteborg, Sweden.

To enhance the game fish supply in Oslofjord, juveniles of sea trout and non-migratory trout have been stocked directly into the fjord without prior adaptation to salt or brackish water. The recapture rate of untagged, non-migratory brown trout may exceed 50% but it is slightly less for sea trout. Results indicate that the value of fish meat recovered surpasses the cost of stocking. Economically, the results of stocking Oslofjord rank among the best in Norway, and they also benefit more anglers than any other fish releases. However, the strains used differ in viability, growth rate and migration pattern, and this leads to management problems. The management techniques for pure stocks of sea trout are not satisfactory for mixed populations of wild and reared fish. So far the results of the experimental stocking have not led to any changes in administration of biological approach to the fjord fisheries.

AASS, P. 1990$_c$. Stocking sea trout and brown trout (*Salmo trutta*) in the Oslofjord, Norway. p. 77-88. *In* M. J. Picken and M. W. Shearer [eds.]. The Sea Trout in Scotland. Proceedings of a Symposium Organized by Scottish Marine Biological Association and Department of Agriculture and Fisheries for Scotland, 18-19 June 1987.

AASS, P. 1990$_d$. Stocking experiments with the Hunder brown trout 1965-1989. Oppland County Environmental Administration Report 9/90. Oslo, Norway.

AASS, P. 1993. Stocking strategy for the rehabilitation of a regulated brown trout (*Salmo trutta*) river. Regulated Rivers: Research and Management 8 : 135-144.

Regulation of the catchment area of the Norwegian river Gudbrandsdalslågen began in 1919. The lowermost power station on the main river was completed in 1964 and is situated about 10 km above the large Norwegian lake, Mjøsa. The lake is the foraging area of the Hunder strain of brown trout, the fastest growing of all Norwegian trout. The running of the power plant has led to a severe reduction in water flows below the dam, and the most important spawning and nursery areas of the Hunder strain has been affected. The natural smolt production has been permanently reduced. The rehabilitation programme has included the construction of a fish ladder through the dam and a fixed minimum flow. A hatchery was built and a stocking programme using the local strain was implemented. The effect of stocking has been the easiest of relief measures to evaluate. Hatchery-reared fish constitute a growing share of the spawning population. During the last three years their share has been close to 60%. Reared fish constitute 30-40% of the trout caught in Lake Mjøsa. The average and best returns of tagged groups have been 25% and 50%, respectively, but return rates are highly dependent on release length and time and place of stocking.

AHVONEN, A. and E. IKONEN. 1993. The effects of stocking time, area, and site, and smolt size on the results of Finnish sea trout tagging experiments. International Council for the Exploration of the Sea Council Meeting Papers, Copenhagen, Denmark, 1993. 15 p.

The results of the Finnish sea trout (*Salmo trutta*) tagging experiments from 1968-1990 were analyzed. The data consists of over 400 tagging groups that were released. The aim was to study the variation in stocking success in terms of recapture and growth rates. In the analysis, the sources of variation that were connected to marine productivity were the year of stocking and the area of release along Finnish coastal waters and rivers. Independent variables connected to stocking techniques were the size of the smolts used in stocking and the time of stocking. The main effects behind the variation in the recapture rate and growth rate were statistically significant. According to the regression analysis, the effect of the smolt size on the recapture rate varied depending on the area, season and site (sea or river) of their release. The best responses for the smolt size were found in the Archipelago Sea and Gulf of Finland; in the Bothnian Bay, the regression was negative. To maximize the stocking success, it seemed to be more profitable to release smolts in the spring rather than the autumn. The recapture rate and the size of caught sea trout did not generally differ in the releases to the sea or river apart from the recapture rate in the Bothnian Bay.

AITKEN, W. W. and E. W. SURBER. 1932. Observations on plantings of fingerling rainbow, brown and brook trout from circular pools. Transactions of the American Fisheries Society 62 : 133-140.

Gregariousness has been a characteristic of all species of trout planted from the circular pools. The probability that the trout in the circular pools use one another as points of reference while swimming is not supported by observations of trout planted from an ordinary pool, unless they use one another as points of reference.

The circular pool fish begin taking natural food almost immediately after planting. Changes in color undoubtedly due to natural food are noticeable within two weeks after planting.

Rainbow trout distributed themselves from the planted pool more quickly downstream than upstream, while the opposite was true with brook and brown trout.

In general, fingerling trout show a tendency to remain for a considerable length of time in the pool in which they were liberated. When thus congregated they are quickly located by their natural enemies.

ALEXANDER, G. R. 1970. Studies on mixed species of trout planted in unfished lakes. Federal Aid Project F-30-R-4, Job No. 3. Michigan Department of Conservation. Lansing, Michigan. 4 p.

ALEXANDER, G. R. 1985. Comparative growth and survival potential of brown trout (*Salmo trutta*) from four wild stocks and one domestic stock. Fisheries Division Research Report No. 1929. Michigan Department of Natural Resources. Lansing, Michigan. 12 p.

Young-of-the-year wild brown trout from four streams and domestic brown trout from Oden Hatchery were stocked in four experimental lakes to determine their relative growth and survival after 2 years of residence in the lakes. Some differences in growth were found suggesting that these were genetically different strains. Gilchrist Creek trout grew significantly more in length than other strains; however, their weight gain was not significantly greater than that for Pigeon River or Sturgeon River brown trout. The Pigeon River and Sturgeon River trout grew better than Au Sable River or domestic trout. No consistent difference in growth was found between Au Sable River and domestic trout.

A habitat or lake effect on brown trout growth was evident. All trout strains grew best in North Twin Lake and second best in Hemlock Lake. There was little difference in trout growth between South Twin Lake and Ford Lake.

The survival rates of the various wild brown trout strains were similar within lakes but differed among lakes. The survival rates of the hatchery strain of brown trout were only about half those of wild fish.

Study results suggest that the intensity of angler exploitation may alter the genetic potential for growth of wild trout populations. The slower growing Au Sable River trout are believed to be exploited more than Gilchrist Creek trout. However, the reduction in Au Sable brown trout growth which has occurred since 1963 is mainly due to reduced fertility caused by reduced input of sewage.

ALEXANDER, G. R. and A. J. NUHFER. 1993. Comparative catchability, growth, and survival of two wild stocks of brown trout. Fisheries Research Report No. 1997. Michigan Department of Natural Resources. Lansing, Michigan.

The catchability and genetic growth potential of trout may be changed, over time, by differential angler harvest of more catchable and faster-growing fish from each cohort. To test this hypothesis, yearling brown trout (*Salmo trutta*) from the Au Sable River and Gilchrist Creek were stocked into Fuller Pond. Brown trout populations from the Au Sable River were believed to have been historically exploited more intensively than those in Gilchrist Creek. We compared their vulnerability to capture by angling, relative growth, and survival over a 2.5 year period. Using artificial flies and lures, Gilchrist fish were approximately four times easier to catch at age 2, and three times easier to catch at age 3 than Au Sable fish. Vulnerability to angling was not correlated with growth rates, as few significant differences occurred in growth. There was also no difference in survival of the two strains during the study period. Differential angler exploitation over time may have altered the catchability of these wild trout stocks. Other factors that could account for observed differences in catchability include genetic dissimilarity of founder stocks, genetic differences due to differences in natural selection between the rivers, or unknown factors. By selection of appropriate brood stocks, fishery managers could double or quadruple brown trout catch rates for some catch-and-release fisheries that are established or maintained by stocking. Conversely, managers could reduce angler exploitation rate, thus permitting trout to grow for a greater length of time in harvested fisheries, by stocking strains that are less catchable.

ANONYMOUS. Undated$_a$. Introduced/pest species in the Canberra region – brown trout. [http://nativefish.www.act.gov.au/lbfish21.htm]

The brown trout was first introduced to the Queanbeyan, Molonglo, Naas, and Cotter rivers, Australia, in 1888. Since this time it has created problems for local and native species. The brown trout has caused/contributed to the decline and displacement of mountain galaxias. Brown trout compete with and prey upon this species. The further introduction of brown trout into other Australian waterbodies must be carefully monitored as they are known to feed on juvenile Macquarie perch and trout cod.

ANONYMOUS. 1914. Report of the Ontario Department of Game and Fisheries for 1913. Toronto, Ontario.

It was reported by Charles Jickling, the Overseer of Perth County, that the German brown trout placed into Otter Creek (in 1913) appear to be growing wonderfully.

ANONYMOUS. 1915. Report of the Game and Fisheries Commission of Ontario for 1914. Toronto, Ontario.

Brown trout introductions were made into Whitemans Creeks in Waterloo county and into waters in the Simcoe area, Norfolk county.

ANONYMOUS. 1919. Report of the Game and Fisheries Commission of Ontario for 1918. Toronto, Ontario.

A total of 44,000 brown trout were stocked into streams at St. Williams (Norfolk County), streams at Hespeler (Waterloo County), a pond at Glencoe (Middlesex County) and Whiteman's Creek (Brant County).

ANONYMOUS. 1930. Report of the Game and Fisheries Commission of Ontario for 1929. Toronto, Ontario.

The rearing of brown trout at the Mount Pleasant Hatchery has been promising. It has been found that this species easily adapts itself to waters which are too warm for other trout, specifically speckled trout. Studies conducted by the State of New York demonstrate that the fishing opportunities in a stream can be extended into areas no longer suitable for speckled trout. Despite all the optimism, the Fish Culture Branch is proceeding with caution and will not introduce brown trout into waters which are still suitable for brook trout.

ANONYMOUS. 1931. Report of the Ontario Department of Game and Fisheries, 1930. Toronto, Ontario.

Seventy thousand brown trout fingerlings were introduced into many suitable lakes in the Kenora District to determine whether or not they will adapt to the local waters. Brown trout were also introduced into Peterborough, Frontenac, Muskoka, Sudbury and other counties.

ANONYMOUS. 1932. Report of the Ontario Department of Game and Fisheries, 1931. Toronto, Ontario.

Currently the culture of brown trout occurs only at the Mount Pleasant Fish Hatchery, where a brood stock is maintained, while the Provincial Fish Hatchery at Kenora has facilities to handle the fish to the fry stage, for distribution into area lakes. Brown trout distribution increased from 70,500 in 1930 to 900,600 in 1931. Brown trout were introduced into numerous counties including Carleton, Grey, Leeds and Perth.

ANONYMOUS. 1933. The Twenty-sixth Annual Report of the Game and Fisheries Department of the Province of Ontario, 1932. Toronto, Ontario.

Currently, only Mount Pleasant and the Codrington Trout Rearing Station are being used to rear brown trout. The stocking policy which guides the planting of brown trout includes only locations which are:

- Streams which in the past contained speckled trout but at present there exists no reason to believe the species will be able to be rehabilitated.
- Lake trout lakes without tributary trout streams.
- Lake trout lakes with tributary streams suitable for spawning trout.
- Regional planting is allowed when needed to provide a complex of diversified conditions for study.

Brown trout planted in the waters of the Muskoka River system have shown positive results and have not interfered with speckled trout. The Kenora Hatchery was used for the limited rearing of eggs for stocking lake trout waters with brown trout in district waters on an experimental basis.

ANONYMOUS. 1934. The Ontario Department of Game and Fisheries Annual Report, 1933. Toronto, Ontario.

Brown trout introductions were made into various lakes including some in Haliburton, Peel, Peterborough, Durham and Waterloo counties.

ANONYMOUS. 1953. Trout planting. Fish Division Pamphlet No. 10. Michigan Department of Conservation. Lansing, Michigan. 5 p.

The stocking of trout within different types of water bodies is examined. Stocking streams with fingerlings can often be difficult. In Gamble Creek, Ogemaw County, the return on three continuous years of stocking brown trout at a rate of 1,000 fingerlings each fall, resulted in only a 0.1% return to the angler. The planting of fingerlings in small lakes is a much more efficient strategy to use to maintain trout fishing, as there appears to be considerable survival from one year to the next, ultimately allowing a large number of fish to contribute to the creel.

For immediate returns to the angler legal-sized fish should be planted. Experiments conducted on various rivers between 1937 and 1945 drew the following conclusions concerning trout planting in streams:

- Six times more brook trout, four times more rainbow trout, and twice as many brown trout were recovered by anglers from early spring and open season planting than fall releases.
- Fall-planted trout did not fan-out over the stream more than those planted in the spring time and were typically captured close to their points of release.
- The average recovery for brown trout planted in the spring or open season was 12.5%.
- The significant effect of the plantings on the catch lasted about two weeks for brook trout and rainbow trout and about four weeks for brown trout.
- Less than one percent of the trout not caught in the season planted contributed to the catch the following season.
- On average, 27% of the total catch was composed of hatchery fish.
- Scatter-planting has no advantage over spot-planting.
- Plantings of rainbow and brook trout gave noticeably higher returns than those of brown trout.
- Twenty-two percent of the total number of brown trout taken were caught more than 40 days following planting, in contrast to 4% of brook and 26% rainbow trout.

The planting of legal-sized trout into small lakes has been found to been equal to or less than that of stream planting when comparing angler returns.

ANONYMOUS. 1954. Investigating the survival of hatchery trout. Wyoming Wildlife 18(4) : 20-25.

There is a widespread belief that hatchery trout are currently maintaining the State's fish populations. While this may be true in certain cases, it is not true for all. There exists variable mortality rates between water bodies.

At Clear Creek, rainbow and brown trout are permanently established species, and are maintained through planting operations. Between 1948 and 1953, 13,420 brown trout were planted into a study area of the stream. In 1952, 4,200 8 inch brown trout were fin-clipped and released. The percentage return to the fishermen's creel the following year was 4.7%, whereas it had been 58.2% the year of the planting. The fish were stocked at a rate of 233 trout/mile yet, there appeared to exist no relationship between stocking rate and catch rate.

Big Laramie River was stocked with brown trout in the fall and spring to determine differential return rates. Trout planted in the fall, measuring between 2 and 6 inches gave a return to the creel of 0.09%, while those between 7 and 9 inches gave a return of 0.96%. Spring-planted brown trout 7 to 9 inches gave a return of 10.28% and those 9 to 12 inches, 19.20%.

ANONYMOUS. 1965. Fish planting formula studies. Federal Aid Project No. F-9-R-12, Job No. C-3, Job Completion Report. New York State Department of Environmental Conservation. Albany, New York.

A creel census was conducted on the Willowemoc Creek during the 1964 trout season to determine how closely the catch rate compared with the 1964 rate predicted by the fish planting formula. The prediction for 1964 was within 14.6% of the actual census estimate, an agreement considered excellent in the face of the number of variables which exist in a trout stream fishery.

In order to produce the desired catch rate for 1964, twice as many fish were stocked than in 1963. It appears that doubling the stocking rate only serves to increase the catch rate of the more capable anglers, since the number of successful trips remained constant in 1963 and 1964 (4,745 and 4,744 successful trips). A limited number of two-year old brown trout were stocked, as in the previous year, they were extremely catchable. Their estimated annual return was 82%.

It was noted that, in both years of census, trout stocked in April had lower returns than those stocked in May. There is considerable evidence that these fish migrated downstream from the census area, since an estimated 6% return of April stocked trout were recorded in the Beaverkill River creel census during 1964.

ANONYMOUS. 1978. Trout liberations in Tasmanian waters 1977-78. Inland Fisheries Commission Annual Report 29(ending 30 June 1978) : 20-24.

In Tasmania there are few waters that need to be stocked with trout on an annual basis. An adequate recruitment level had been demonstrated over recent years by an electrofishing survey. The Inland Fisheries Commission arranges stocking from time to time in waters with unsuitable or insufficient grounds for spawning. Details of liberations of wild, adult brown trout from the central Highlands in 1978 are given together with details of the liberation of brown trout and rainbow trout in 1977.

ANONYMOUS. 1982. Annual Report of the Minister of Natural Resources of the Province of Ontario. Toronto, Ontario.

During the fall of 1991, 290,000 native brown trout eggs were collected from both the Ganaraska and Sydenham rivers. They are being raised to the yearling size at the Codrington Fish Culture Station and will be available for stocking in the spring of 1983. A disease-free brown trout brood stock is being developed at Codrington to ensure the success of the stocking projects.

ANONYMOUS. 1983. Annual Report of the Minister of Natural Resources of the Province of Ontario. Toronto, Ontario.

The stocking of the brown trout in Ontario waters stopped in the 1960s due to suspicions that the species was spreading disease wherever it was stocked. Recently, the fish has received a clean bill of health and stocking projects are once again proceeding. In the fall of 1982, 71,000 brown trout fingerlings were stocked into Lake Ontario, Summit Lake and the Ganaraska and Sydenham rivers. The following spring (1983) the same waters were stocked with a total of 139,000 yearlings.

ANONYMOUS. 1998. Investigations into causes of and solutions for recent declines in survival of trout stocked in Lake Huron. Federal Aid Project F-53-R-14, Study No. 469, Performance Report. Michigan Department of Natural Resources. Lansing, Michigan.

Two strains of brown trout were selected for study, Wild Rose and Seeforellen. The stocking phase of this evaluation was completed in 1995. Returns of the two strains continued to be monitored in 1997. In 1996, a two-year comparison of stocking methods began: two study lots were stocked each year, one lot was stocked offshore in Thunder Bay, and a second lot stocked using conventional techniques from the beach. In 1996, Wild Rose strain was used for both groups; in 1997, Seeforellen strain was used. Relative survival is being measured using creel census. The stocking dates were delayed until the June peak in alewife spawning density was reached to reduce losses to predation. Also, beginning in 1991, the selected study strains were introduced. The 1991-95 year classes of brown trout increased from 500 in 1991 to 2,284 in 1992 and 3,908 in 1993. Harvest steadily declined thereafter, however, and was only 1,198 in 1997. In Thunder Bay to date, Seeforellen and Wild Rose strains produced similar return to creel. Both strains produced significantly better harvests than Plymouth Rock strain. Seeforellen strain grew significantly faster than the other strains. During the July 1997 Alpena Brown Trout Festival, the proportion of Seeforellen strain was not significantly different than that of Wild Rose ($P>0.05$), but by July, age 3 Seeforellen strain was significantly larger ($P<0.05$). A similar study was conducted on Lake Charlevoix. Creel census was conducted there from 1993-96 to assess the performance of three strains: Seeforellen, Wild Rose and Plymouth Rock. The catch rates (fish per 100 angler hours) were similar for Seeforellen and Wild Rose strains of the same age. However, in 1993 and 1994 catch rates of both Seeforellen and Wild Rose strains were at least 5 times those for Plymouth Rock strain of the same age. Paired Seeforellen and Wild Rose stocked in 1994 and 1995 survived poorly and fishing success for brown trout in Lake Charlevoix sharply declined in 1995 and 1996. Causes of the recent declines in brown trout catches at Thunder Bay and Lake Charlevoix have not been identified, but declining numbers of alewives in the spawning run may have contributed to the relapse.

ANONYMOUS. 1999_a. Successful spawning of brown trout in North Park provides more opportunities for anglers. Wildlife Report: News Release from the Colorado Division of Wildlife. Denver, Colorado.

For the twentieth year the brown trout spawn-taking operation at North Delaney Butte Lake has been successful. It is estimated that from the 1.1 million eggs procured, at least half of them will hatch successfully, producing 550,000 fingerlings to be stocked in lakes and reservoirs across Colorado in the spring of 2000. All of the fish stocked will be whirling disease negative. This disease, though often carried by brown trout does not usually affect a population to the extent that the infection drastically reduces population numbers.

ANONYMOUS. 1999_b. Smolting characteristics of wild and hatchery-reared brown trout. Center for Environment, Fisheries and Aquaculture Science. Trout News 7 : 36-37.

APPLEGATE, R. L., D. L. SHUMATE and C. M. HOFFMAN. 1966. Evaluation of trout stocking practices. Federal Aid Project F-13-R-3, Job No. 1. Virginia Commission of Game and Inland Fisheries. Richmond, Virginia. 14 p.

ARCHER, D. L. 1967. Fisheries investigations in lakes and streams: Trout tagging study. Federal Aid Project F-10-R-2, Job No. 1. South Carolina Division of Game and Boating. Columbia, South Carolina. 7 p.

ARIAS, J., S. RODRIGUEZ, L. SANCHEZ and P. MARTINEZ. 1993. Genetic diversity analysis and differential stocking incidence in brown trout populations from Galacia. p. 203-208. *In* A. Cervino, A. Landin, A. de Coo, A. Guerra and M. Torre [eds.]. Actas del IV Congreso Nacional de Acuicutura, Centro de Investigaciones Marinas, Pontevedra, Spain.

An allozyme electrophoretic analysis was carried out to evaluate the impact of stocking, and to assess the amount and distribution of genetic variation among brown trout populations in Galicia. Detection of genetic markers permitted us to monitor the incidence of stocking practices in different media. The low viability of stocking individuals within river populations is remarkable, while in non-flowing waters a large introgression was revealed. Gene diversity analysis demonstrated an important genetic differentiation among populations, mostly within drainages, while the stocking hatcheries exhibited a great genetic homogeneity. Genetic distance between indigenous and stocking groups shows great genetic divergence.

ARIAS, J., L. SANCHEZ and P. MARTINEZ. 1995. Low stocking incidence in brown trout populations from northwestern Spain monitored by LDH-5* diagnostic marker. Journal of Fish Biology 47 (Supplement A) : 170-176.

Brown trout (*Salmo trutta*) is one of the most valuable species inhabiting river drainages in Galicia (northwestern Spain). The influence of man, through overfishing and pollution, is thought to have caused the decline of trout in Galician rivers. To balance the possible population decline, Galacian rivers have been stocked extensively with a brown trout stock of German origin during the last 30 years. In this study, the incidence of stocking practices has been investigated by an LDH-5* genetic marker. A very low number of stocked individuals have been observed within river populations, despite the long period of repopulation. Only 8 out of the 44 populations analysed showed a limited number of individuals of hatchery origin. Most stocked individuals detected were 0+ age, and showed poor condition factor (K<1). Environmental factors (muscular stamina and food habits) and genetic factors (different selective conditions in hatchery medium) are invoked to explain the low viability of hatchery fish observed in this study.

AULT, T. R. and R. W. G. WHITE. 1994. Effects of habitat structure and the presence of brown trout on the population density of *Galaxias truttaceus* in Tasmania, Australia. Transactions of the American Fisheries Society 123(6) : 939-949.

To examine the effect of introduced brown trout (*Salmo trutta*) on populations of native *Galaxias truttaceus* (Galaxiidae), known locally as spotted galaxias, population abundance models based on the habitat use patterns of *G. truttaceus* were used to compare streams with and without brown trout. In selected streams in southeast Tasmania, habitat use by *G. truttaceus* was examined with respect to four principal components extracted from eight habitat variables. Different size-classes of *G. truttaceus* displayed varying non-random patterns of habitat use, shifting from shallow, open habitats, to deep, cover rich habitats with increasing size. All size-classes preferred slow-flowing sections to fast-flowing sections. Population abundance models were constructed for three size-classes of *G. truttaceus*, and given the hydrologically variable nature of streams studied, all of the models were reasonably successful in explaining variation. The application of the models to streams containing brown trout indicated that the presence of brown trout was more important than habitat characteristics in determining the abundance of *G. truttaceus*. In streams with brown trout, the density of each size class of *G. truttaceus* was substantially less than that expected on the basis of habitat characteristics. The study provides strong evidence that brown trout adversely affect populations of *G. truttaceus*, because habitat differences are quantitatively accounted for when streams with and without brown trout were compared.

AURELLE, D., S. LEK, J.-L. GIRAUDEL and P. BERREBI. 1999. Microsatellites and artificial neural networks: Tools for the discrimination between natural and hatchery brown trout (*Salmo trutta*) in Atlantic populations. Ecological Modelling 120(2-3) : 313-324.

Artificial Neural Networks (ANN) were applied to microsatellite data (highly variable genetic markers) to separate genetically differentiated forms of brown trout (*Salmo trutta*) in south-western France. A classic feed-forward network with one hidden layer was used. Training was performed using a back-propagation algorithm and reference samples representing the different genetic types. The hold-out and the leave-one-out procedures were used to test the validity of the network. They were chosen according to the populations and the questions analysed. The informative content of the different variables used for the distinction (the alleles of the different loci) was also evaluated using the Garson-Goh algorithm. The results of learning gave high percentages of well-classified individuals (up to 95% for the test with the hold-out analysis). This confirms that ANNs are suitable for such genetic analyses of populations. From a biological point of view, the study enabled evaluation of the genetic composition and differentiation of different river populations and of the impact of stocking.

AVERY, E. L. 1975. Evaluation of stocking fingerling trout in a "two-story" trout lake. Research Report 83. Wisconsin Department of Natural Resources. Madison, Wisconsin. 4 p.

On May 31, 1973, 4,500 brown trout and 4,500 rainbow trout fingerlings were stocked in Nebish Lake. Trout ranged from 3.0 to 4.2 inches in total length. Large smallmouth bass captured in fyke nets set in early June 1973 were satiated and regurgitated half a dozen fingerling trout during handling. Only one brown trout was captured during fyke netting and electrofishing conducted in the spring and fall of both 1973 and 1974. Survival of fingerling trout was essentially nil after 5.5 months in Nebish Lake. Total angler harvest consisted of one rainbow trout caught by an ice fisherman in January 1975. Growth of the trout which survived in Nebish Lake was excellent.

Stocking fingerling trout 3-4 inches in length in a "two-story" lake containing smallmouth bass and an abundant, slow-growing yellow perch population is not recommended because of the high probability of poor trout survival due, at least in part, to fish predation.

AVERY, E. L. 1978. The influence of chemical reclamation on a small brown trout stream in Southwestern Wisconsin. Technical Bulletin No. 110. Wisconsin Department of Natural Resources. Madison, Wisconsin. 35 p.

The present study was initiated to more thoroughly quantify effects of chemical treatment and total fish removal on a domesticated brown trout (*Salmo trutta*) population, the sport fishery, and the aquatic invertebrate community in a small southwestern Wisconsin trout stream. A culvert-type fish barrier was installed in the middle of the study zone prior to chemical treatment to determine its effectiveness in preventing reinvasion of forage fishes and to quantitatively document added benefits this practice might have over and above those derived from chemical treatment alone.

Seas Branch Creek was treated with antimycin A in October 1972 to eradicate a forage fish population consisting primarily of suckers, stonerollers, daces and darters. The aquatic invertebrate community, fish populations, and sport fishery for stocked brown trout were studied for two years before and two years after chemical treatment.

Significant improvements occurred in the growth, standing crop and production of stocked brown trout after removal of up to 1,445 kg/ha of forage fish. The number of invertebrate orders represented in at least 30%

of the trout stomachs also doubled, indicating that interspecific competition for food existed before treatment. Survival of trout did not improve following forage fish removal, nor did it improve significantly after a reduction of 50% in stocking density. Poor survival and low carrying capacity of the stream were related to the lack of permanent stream cover.

The sport fishery was primarily of local interest; over 70% of the anglers fishing the stream before and after treatment live within a 10-mile radius. The number of fishing trips and total fishing pressure increased following treatment but total harvest and catch ratio declined. The absence of trout >30 cm during the first year after treatment was primarily responsible for the total decline in harvest during the two-year, post-treatment study.

A culvert-type fish barrier proved effective in preventing access upstream to forage fishes. Reinvasion of the lower half of the treated stream (below the barrier) was led by the central stoneroller (*Campostoma anomalum*) and most species present before treatment returned by the end of the first year. After two years 90% of the average pretreatment density and 55% of the average pretreatment biomass of forage fish were present below the barrier; only 14% of the average pretreatment density and 3% of the average pretreatment biomass were present above the barrier. Of the 21 species originally present, all were present below the barrier two years after treatment, while only nine were observed above the barrier. Most of the latter gained entrance during a temporary wash-out of the fish barrier in a period of exceptionally high run-off.

In order of numerical importance, Trichoptera, Diptera, Coleoptera, Epheroptera, and Amphipoda were the most important orders of aquatic invertebrates present before and after treatment. Mean invertebrate density declined immediately after treatment but returned to normal within four to seven months. Responses of the more important genera of invertebrates to the antimycin treatment are discussed.

BACHMAN, R. A. 1984. Foraging behavior of free ranging wild and hatchery brown trout (*Salmo trutta*) in a stream. Transactions of the American Fisheries Society 113 : 1-32.

Wild brown trout (*Salmo trutta*) in a fertile, high conductivity stream in central Pennsylvania were observed from camouflaged towers for three consecutive years in order to quantify the diurnal feeding and social behavior of undisturbed adults. The foraging behavior observed was characterized in general as one of net energy maximization effectuated principally by cost minimization. Individuals ranging in age from young of year to 8 years spent 86% of foraging time in a sit and wait search state, using discrete, energy saving foraging sites year after year, and fed mainly off drift, taking less than 15% of their food items directly off the bottom. Feeding rates decreased with age, were highest in spring and fall, and showed little effect of time of day except for short peaks at dusk in May and June. The home range of most individuals was established in the first or second year of life and changed little thereafter. The mean size of the home range of individuals was 15.6 m^2 and decreased slightly during the first four years of growth. No individual had exclusive use of any home range and no clearly defined territory could be described for any fish. Rather, the social structure evidenced is best described as a cost-minimizing, size dependent, linear dominance hierarchy of individuals having overlapping home ranges. There was no apparent correlation between dominance and site selection with respect to distance to cover or feeding rate. Use of overhead cover ranged from 17% or less of daylight hours for wild brown trout of age-group 2 to no more than 43% for age-group 5. Length was asymptotic at 40 cm. A rectangular hyperbola described well the overall growth curve of fish in this population, half of the asymptotic length being attained at the age of 23 months. Hatchery brown trout, introduced for experimental purposes, fed less, moved more, and used cost-minimizing features of the substrate less than wild trout. It is postulated that high energy cost is a major cause of mortality among hatchery-reared brown trout stocked in streams, that at high population densities foraging sites are limiting factors, and that growth rate of drift-feeding salmonids is density-independent.

BAGENAL, T. B. 1969. Relationship between egg size and fry survival in brown trout (*Salmo trutta*). Journal of Fish Biology 1 : 349-353.

There exists variability between egg sizes from one female brown trout to the next. Past studies have proven that larger eggs result in larger fry, and this assumption was used, along with hatchery fish, to determine the extent of reproductive success of fish in the Lake District. It was concluded that under natural conditions, the brown trout in the Lake District which are produced from large eggs have a significantly better chance at surviving than those derived from small eggs.

BALL, G. 1990. Municipal hatchery report #7: Brown trout, January 1989 to July 1990. Sport Fishing Development Program, The City of Sault Ste. Marie. Sault Ste. Marie, Ontario. (Abstract only)

Ontario's first municipally run fish hatchery in Sault Ste. Marie has successfully completed its first brown trout stock-out. The 1990 production totaled 40,863 fish. The Lake Superior system received 17,010 (Left Ventral clip) while the Lake Huron system received 21,820 (Right Ventral clip). The balance of fish were placed in inland waters (2,033). The 1989-90 survival rate from eyed-eggs to yearling release was 66.34%.

BANKS, S. M. and P.W. BETTOLI. 1999. Identification of the factors necessary for successful trout reproduction in Tennessee Tailwaters. Presented at the 1999 Southern Division of the American Fisheries Society midyear meeting held in Chattanooga, Tennessee. (Abstract only)

Tennessee tailwaters are routinely stocked with brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) to sustain put-and-take and put, grow, and take fisheries. Natural reproduction is known to occur in some Tennessee tailwaters. Natural reproduction can enhance the quality of a fishery and reduce the reliance on hatcheries to maintain a fishery. However, current stocking regimes ignore natural reproduction as a source of population enhancement because the subject is not well researched. The factors which control trout reproduction in Tennessee tailwaters are poorly understood. The objective of this study is to identify the factors necessary for natural reproduction to occur. This study is focusing on four east Tennessee tailwaters; little or no natural reproduction is thought to occur in two rivers (Clinch and Hiwassee), but substantial reproduction has been documented in two other rivers (South Fork of the Holston and Watauga). Complete censuses of spawning activity commenced in October 1998 and will continue through two spawning seasons. In addition to assessing habitat quality, other factors such as fecundity and brood stock size will be investigated.

BARBAT-LETERRIER, A., R. GUYOMARD and F. KRIEG. 1989. Introgression between introduced domestic strains and Mediterranean native populations of brown trout (*Salmo trutta*). Aquatic Living Resources 2(4) : 215-223.

Introgression between introduced domesticated stocks and natural populations of brown trout (*Salmo trutta*) was investigated by protein electrophoresis in 3 Mediterranean rivers. From each river, one undisturbed site and one, closely located, yearly stocked site were sampled. Comparison of the electrophoretic variation observed in samples from the undisturbed sites with that in the introduced hatchery strains revealed several especially "domestic" variants. The genetic control of these variants was demonstrated by breeding experiments. The samples collected from the stocked sites showed introgression rates ranging from approximately 0 to 40%. The genotype frequencies observed in these samples suggested that no reproductive barrier exists between introduced and native stocks and that they form random mating populations.

BARKER, R. E. 1955. The fate of hatchery trout in the wild. Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissioners 35 : 112-116.

The disappearance of hatchery-raised trout after being planted is an accepted phenomenon but, unfortunately, no adequate explanation of all the reasons for disappearance has been made. In the three year period between 1949 and 1952, a number of trout tagging studies on hatchery planted rainbow and brown trout between 6 and 12 inches in length were conducted. These plantings were made in both streams and lakes, at different times of the year and different means were used to obtain the return of tags to the New Mexico Department of Game and Fish.

Of the 7,190 rainbow trout tagged and planted in streams, only 18.8% of the tags were ever recovered; of the 1,200 browns tagged and planted about the same time in the same streams, only 1.5% were recovered.

What happens to trout after planting was not determined but the study did indicate that the best return was from trout stocked in the spring and early fall rather that those planted in late fall and winter.

BARLAUP, B. T. and Å. ÅTLAND. 1994. Stocking of brown trout (*Salmo trutta*) cohorts after liming – effects on survival and growth during five years of reacidification. Water, Air and Soil Pollution 72 : 317-330.

The chronically acid Hovvatn and the adjoining pond Pollen were limed in March 1981. During the first four years after the liming, a total of 11,437 brown trout were stocked in the two locations. The fish population was monitored by annual test-fishing in a five year period following the liming. The stocking material constituted 6 cohorts and included fish stocked at age 0+, 1+ and 2+. The stocking program assured a 7.9 times higher density of fish/ha in Pollen than in Hovvatn. Consequently, the fish from Hovvaatn grew significantly better and had a significantly higher condition factor than fish in Pollen. Monitoring of water chemistry showed that the cohorts were exposed to a gradual acidification process, abrupted by episodic events of severe acidification. Within 2-3 years after the liming, the locations had reacidified to conditions which were considered critical for fish. However, the acid-induced increase in mortality appeared 1-2 years later than what was expected from water chemistry data. This discrepancy could most likely be ascribed to the existence of water chemical refugia which enhanced the survival of the fish. Recaptures were significantly correlated to pH, Ca, labile-Al and ANC. Growth were significantly reduced through the reacidification period. Estimated yield showed that fish stocked at age 2+, as opposed to fish stocked at a younger age, managed to turn the high food availability into growth rates before the reacidification retarded growth and survival.

BARLAUP, B. T., A. HINDER, E. KLEIVEN and R. HOGBERGET. 1996. Incomplete mixing of limed water and acidic runoff restricts recruitment of lake spawning brown trout (*Salmo trutta*) in Lake Hovvatn, southern Norway. Report. Institute of Zoology, Department of Animal Ecology, University of Bergen. Bergen, Norway. 39 p.

Repeated liming of Lake Hovvatn during the 1981-95 period assured successful reintroduction of lake spawning brown trout (*Salmo trutta*). However, stocking of trout was necessary to maintain the population as natural recruitment was not recorded until 1989-95 and then in low numbers. The poor recruitment was associated with low survival during early life stages (pre-hatch) as shown by the 0.5, 3.5, 0.9 and 1.0% of live embryos found in natural redds during the 1992-95 period, respectively. The low survival was most likely caused by the combination of shallow spawning areas (<2.0 m) and acidic runoff (pH 4.0-4.8) which overlaid the limed part of the water body during the ice covered period. Varying meteorological conditions caused variation in both the depth (1.5-2 m) and the duration (1-4 months) of the acid layer between years.

This variation seemed to produce large year class fluctuations of natural recruits and it is not known whether the population can be self maintained. It is therefore concluded that this type of episodic acidification poses a major threat to lake spawning salmonids, and that it can efficiently retard or inhibit biotic recovery towards pre-acidified conditions expected as a result of liming. Addition of limestone gravel (8-32 mm) onto spawning grounds was an efficient alternative liming strategy as 33-36% live embryos were found in this substrate. Conversely, the trout actively avoided additions of shells, a behaviour most likely caused by the small particle size of shellsand (3-7 mm) relative to natural spawning gravel.

BARTEL, R. 1987. Distribution, migration and growth of tagged sea trout (*Salmo trutta*) released into the catchment area of the Wieprza River. Morskiego Instytutu Rybackiego Gdynia (Bulletin of the Sea Fisheries Institute) 18(3-4) : 14-22.

Returns from tagged sea trout released into the Wieprza and Grabowa rivers amounted to 0.2 and 5.2%, respectively. In the first year after release the fish attained 51.2 cm and 1,701 g; in the second year - 62.3 cm and 3,550 g. Effectiveness of stocking was 125.4 and 65.3 kg/1,000 smolts released into Grabowa river. Tagged sea trout were caught mainly in coastal waters of Pomerania and in the Gulf of Gdansk: 2.4% were caught in spring of the first year, and 41.7% in spring of the second year. Fish were rare here in the summer: 0% in the first and 5.2% in the second year, while in autumn the respective percentages increased to 13.3 and 29.4%. Most fish were caught in the Gulf of Gdansk in winter: 58.7% in the first and 57.1% in the second year.

BARTEL, R. 1988. Variability of sea trout returns as shown from long term tagging experiments with hatchery-reared parr and smolts. Morskiego Instytutu Rybackiego Gdynia (Bulletin of the Sea Fisheries Institute) 19(5-6) : 27-36.

The results are presented of tagging experiments conducted on sea trout (*Salmo trutta*) in Poland during the period 1958-74. The influence of release period, place of fish release, age of smolts and smolt size on the tagging results are considered. A brief examination is also made of the possible influence of the tagging procedure used.

BARTEL, R. 1993. Present situation of the Vistula sea trout. International Exploration of the Sea Council Meeting Papers, Copenhagen, Denmark, 1993. 16 p.

The aim of the paper was to show a present status of Vistula sea trout (*Salmo trutta*). Pollution of water in the Vistula River has reduced the population size of Vistula sea trout. When the Vistula River was dammed in 1969 the Vistula sea trout population drastically dropped. In 1972-1992, from 320,000 to 314,000 smolts and from none to 1,446,100 alevins were released into the Vistula River yearly. In this period the sea trout catches in the Vistula River varied from 30.9 to 129.1 tonnes. Effectiveness of stocking based on sea trout catches in the Vistula mouth and the Vistula River was an average 295.5 kg/1,000 smolts.

BARTEL, R., H. AUVINEN and E. IKONEN. 1988. Results of transfer experiments with the Vistula and Isojoki sea trout (*Salmo trutta*). International Council for the Exploration of the Sea, Collected Papers, Copenhagen, Denmark, 1988. 26 p.

Tagged sea trout (*Salmo trutta*) from the Vistula (Poland) and Isojoki (Finland) Rivers were released into the Vistula River mouth and into the Gulf of Finland. Vistula sea trout released into the Vistula River mouth were less frequently caught (75%) in and nearby the place of their release than were Isojoki sea trout released in the same place (92.3%). Finnish sea trout seldom migrated to ICES (International Council for the Exploration of the Sea) Sub-divisions 24 and 25.

BARTEL, R. and P. DEBOWSKI. 1996. Stocking of sea trout (*Salmo trutta trutta*) smolts in Poland. Part 1: Preliminary analysis of tagging experiments. Archiwum Rybactwa Polskiego 4(1) : 5-18.

In 135 experiments, 183,206 sea trout (*Salmo trutta trutta*) smolts were tagged and released into the Vistula River system, to the Pomerania rivers, and to the Bay of Gdansk (Poland) in 1961 through 1986. The average result was 127.3 kg of recaptured fish per 1,000 of released smolts and the range was from 0 to 1,116 kg. The most successful was stocking to the sea (mean 251.8 kg), less tagged fish were recaptured from Vistula system (120.8 kg) and from the Pomeranian rivers (55.9 kg per 1,000 smolts). High correlation between recaptures in successive years following release suggests that a short period after stocking determined the overall effects.

BARTON, B. A. 2000. Salmonid fishes differ in their cortisol and glucose responses to handling and transport stress. North American Journal of Aquaculture 62 : 12-18.

Uniformly acclimated juvenile salmonid fishes subjected to 30 seconds of handling or 2 hours of transport stressors showed differences in the magnitude of poststress plasma cortisol and glucose increases. Lake trout (*Salvelinus namaycush*) had the highest maximum plasma cortisol after handling (143 ng/mL), rainbow trout (*Oncorhynchus mykiss*) had the lowest levels (43 ng/mL), and brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) had intermediate levels (111 and 89 ng/mL, respectively). Lake trout had the highest peak post-transport plasma cortisol (124 ng/mL) compared with brook trout (69 ng/mL) and rainbow trout (57 ng/mL). Peak post-handling plasma glucose levels were highest in brown trout (257 mg/dL) followed by brook, rainbow and lake trout (177, 153 and 150 mg/dL, respectively). Rainbow trout, however, had the highest peak plasma glucose concentration (223 mg/dL) after transport, and lake trout the lowest (143 mg/dL). Species considered as most stressed based on plasma cortisol elevations were not necessarily so as indicated by changes in glucose. Thus, the evaluation of handling or transport stress in hatchery-reared salmonid fishes cannot rely solely on a single indicator nor on direct comparison with other species.

BARTON, B. A. and F. I. McNEIL. 1981. A review of brown trout (*Salmo trutta*) culture and stocking strategies. Fisheries Branch, Ontario Ministry of Natural Resources. Toronto, Ontario. 25 p.

After a review of brown trout culture and stocking literature the following recommendations were offered: (1) Culture of brown trout in Ontario should be carried out at the Codrington Fish Culture Station; (2) All potential brood stock obtained from wild populations should be analyzed for disease agents, particularly furunculosis, prior to use; (3) Brood stock suitable for Great Lakes planting should be selected from presently occurring Great Lakes stocks during their fall upstream migrations; (4) To rehabilitate stream populations of brown trout in southern Ontario, local wild stocks would be most suitable if available; (5) For stocking brown trout solely to provide artificial opportunities, particularly in closed waters, domestic or semi-wild strains would be preferable (generally, stocking brown trout for this purpose is not recommended as rainbow trout or F_1 splake may be more suitable); (6) spring yearlings rather than fall fingerlings should be used for stocking, particularly in the Great Lakes where it would be desirable to establish migratory runs in tributary streams; and (7) a strategy of "scatter planting" should be employed when stocking brown trout; that is, stock at a number of locations and/or on different days instead of using a single plant.

BARWICK, D. H. and W. R. GEDDINGS. 1985. Stocking success of brown trout and two strains of rainbow trout in Jocassee Reservoir, South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39 : 28-33.

The relative success of the Walhalla strain of brown trout (*Salmo trutta*) and the Wytheville and Winthrop strains of rainbow trout (*S. gairdneri*) was evaluated for 2 years in a put-grow-and-take stocking program in Jocassee Reservoir. Gillnet catches of brown trout increased during the 2 year study, while catches of rainbow trout of both strains declined rapidly after stocking and no rainbow trout were netted during the second year of the study. A total of 11.4% of the stocked brown trout and 1.6% of the rainbow trout were harvested by fishermen during the study. Poor survival of rainbow trout in Jocassee Reservoir may be related more to the size of fish stocked than to different strain-specific characteristics.

BEAUDOU, D., D. BARIL, B. ROCHE, M. LE BARON, G. CATTANEO-BERREBI and P. BERREBI. 1995. Recolonization in a devastated Corsican River: Respective contribution of wild and domestic brown trout. Bulletin Français de la Pêche et de la Pisciculture 337-339 : 259-266.

The present study was carried out in the Abatesco River basin on the eastern coast of Corsica. In September 1989, this small river basin was devastated by a storm spate. In the main river bed, the destruction of the riparian vegetation and the perturbation of the habitat led to a nearly complete loss of the benthic fauna and the brown trout (*Salmo trutta*) populations. About 20,000 domestic fingerlings (5 cm mean length) were stocked during the spring of 1990 in the main river and its tributaries. In subsequent years, stocking practices were limited to the head of the basin. Fishing was prohibited until March 1993. Two sites were sampled five times from September 1989 to September 1993 to evaluate trout densities. In June 1993, 30 individuals were sampled in the Abatesco to investigate allozyme polymorphism. Recolonization required at least two years. Although the exact influence of stocking practices was difficult to evaluate, we found that brown trout restoration was mainly due to the populations of the tributaries, which had been less disturbed by the spate. The genetic analyses showed that, in June 1993, 92% of the trout carried the wild allele LDH-5*105 and 72% the endemic Corsican allele LDH-3*40, which is generally only found in basin head populations. Thus, this study has shown that the wild population was primarily restored by the surviving individuals, particularly those from the tributaries that escaped the spate.

BEAUDOU, D., G. CATTANEO-BERREBI and P. BERREBI. 1994. Genetic impacts of trout (*Salmo trutta fario*) stocking practices on *in situ* populations: Case of the Orb basin (Herault). Bulletin Français de la Pêche et de la Pisciculture 332 : 83-92.

The aim of this work is the evaluation of the genetic impact of the stocking practices, in the Orb River basin of southern France. The effectiveness of the stocking policy, and its impact on the genetic pool of the natural populations, was followed in the Orb basin, where the number of trout stocked each year between 1966 and 1989 was equivalent to that of the natural populations. Trout collected by electro-fishing from this river and two of its tributaries, the Tes and the Mare, were characterized by starch gel electrophoresis at 25 loci. The three localities were stocked for at least twenty years, but the intensity of stocking and the stages used differed. The LDH-5* locus, which codes for the eye-specific lactate deshydrogenase in brown trout, distinguishes between Atlantic and Mediterranean French populations, with two allelic forms respectively LDH-5*100 and LDH-5*105. The hatchery-reared trout are Atlantic strains, that is why the LDH-5* represents a genetic detectable tag for the four hatchery strains, currently stocked in the Mediterranean populations of the Orb basin. The hatchery strains show high frequencies of LDH-5*100 (87.5 to 100%). The three populations collected in the Orb basin show frequencies of LDH-5*105 between 86 to 97%. This high percentage of LDH-5*105 shows the poor interbreeding between natural and hatchery-reared trout. It may indicate that the stocked trout do not reach the age of maturity.

BEAUDOU, D., A. ROBERT DE and P. BERREBI. 1994. Trout (*Salmo trutta fario*) stocking practices in French Mediterranean region: Case of the Orb basin. Bulletin Français de la Pêche et de la Pisciculture 332.

Since the end of the 19th Century, stocking practices were developed to control brown trout population densities. The stocking practices for the rivers in the French Mediterranean region between 1984 and 1987 were analysed using the records of the local fishing associations. Most of the fish introduced were brown trout (*Salmo trutta fario*). In absence of a synthesis, a historical balance-sheet (from 1966 to 1989) of the brown trout stocking practices was realized for Herault country and the Orb River basin. The stocking practices are generalized, but differ among localities and administrators.

BERG, S. and J. JORGENSEN. 1991. Stocking experiments with 0+ and 1+ trout parr (*Salmo trutta* L.) of wild and hatchery origin: 1. Post-stocking mortality and smolt yield. Journal of Fish Biology 39(2) : 151-170.

Wild and hatchery-reared 8-12 month old (5-8 cm) trout (*Salmo trutta*) were stocked in tributaries of the River Gudena. Mortality was examined by means of electrofishing. Repeated electrofishing and mortality caused a small increase in mortality. The daily instantaneous mortality rate (Z) was high during the first 2 months after stocking, ranging from 0.0070 for wild trout to 0.0326 for domestic trout at a stocking density of one trout per m^2 and from 0.0206 (wild trout) to 0.0888 (domestic trout) at a stocking density of two trout per m^2. Two months after stocking, Z decreased drastically ranging from 0.0007 (wild trout) to 0.0067 (domestic trout), when stocked first generation hatchery trout showed Z equal to domestic trout. Wild trout resident in the experimental stream were negatively affected by the introduction of domestic trout and wild trout from another stream, at a stocking density above the carrying capacity. It is concluded that the higher mortality of domestic trout was caused by changes in food, feeding and exercise, possibly combined with the lack of selection in the hatchery. Smolt yield at age 2+ was 3.2% (0+ trout stocked in the fall) – 7% (1+ trout stocked in the spring) of the domestic trout stocked (approximately one-sixth to one-third of natural populations) and 65.2-68.7% of the domestic trout present before the smolt run. For first generation hatchery trout of wild origin the corresponding figures were 7.3% (age 0+) and 93.4%, and for wild trout introduced to the experimental stream they were 11.1% (age 0+) and 39.8%.

BERREBI, P., C. POTEAUX, M. FISSIER and G. CATTANEO-BERREBI. 2000. Stocking impact and allozyme diversity in brown trout from Mediterranean southern France. Journal of Fish Biology 56(4) : 949-960.

Analysis of trout from 13 stations on the Mediterranean slopes of the French Pyrenees by 31 presumptive enzyme loci demonstrated the major impact of restocking programmes. Although the annual introgression resulting from these introductions was small, the accumulation of genes of Atlantic origin has resulted in a change in allele frequencies. Genetic disequilibria within and between loci exist. Introgression by genes of domestic (hatchery) origin varied from 0-77% among stations. Natural Mediterranean populations show no detectable geographical structure. There was a direct relation between the degree of introgression and heterozygosity. However, restocking could not explain all of the observed genetic disequilibria.

BETTROSS, E. 2000. Savanna River trout stocking evaluation. Presented at the 2000 Southern Division of American Fisheries Society midyear meeting held in Savannah, Georgia. (Abstract only)

Water temperature, dissolved oxygen, fish species assemblage, and creel data were collected from the 36 mile section of the Savannah River tailwater between Clarks Hill Dam and the New Savannah Bluff Lock and Dam for the purpose of evaluating stocking trout. A test stocking of 10,000 rainbow and 9,500 brown trout was made at the request of the Savannah River Trout Association. Five hundred of each species was tagged. Water temperature exceeded criteria previously used for classifying secondary trout streams in northwest Georgia at most sample locations. Dissolved oxygen concentrations in the uppermost portion of the study area were below minimum state water quality standards for trout water (5.0 mg/l) from July through September. Dissolved oxygen increased but water warmed rapidly as it flowed over the Augusta shoals, 16 miles downstream from Clarks Hill Dam. In the upper 15 miles of the study area, where temperatures remained marginally cool enough for trout survival, oxygen levels were severely depressed. Farther downstream, where oxygen levels were reasonably high, temperature became too high to expect significant trout survival. The study area supports a diverse assemblage of warmwater fish species, many of which could be expected to compete with or prey upon stocked trout. No trout tags were returned and only two trout were recorded in the creel survey. The studied reach of the Savannah River is unable to support trout due primarily to low dissolved oxygen and high temperature.

BIAGI, J. and C. R. MARTIN. 1992. Walton Experimental Station: The effect of three stocking rates on growth, survival and angler success and harvest of brown trout on a 27 km section of the Chattahoochee River. Federal Aid Project F-26-R-19, Study XVI, Final Report. Georgia Department of Natural Resources. Atlanta, Georgia. 30 p.

Three stocking rates (50,000, 100,000 and 150,000) were evaluated to determine the survival and growth of brown trout in the Chattahoochee River, Morgan Falls Tailwater.

BIANCO, P. G. 1998. Freshwater fish transfers in Italy: History, local changes in fish fauna and a prediction on the future of native populations. p. 167-185. *In* I. W. Cowx [ed.]. Stocking and Introduction of Fish. Fishing News Books, Blackwell Science, Ltd. MPG Books, Ltd. Bodmin, Cornwall, Great Britain.

In Italy, 73 naturalized fish species (48 native, 25 exotic) are currently found in public waters. About 50% of introductions have taken place during the last 20 years. If this trend continues a further 5-10 exotic species are expected by the turn of the century. Regional trends in species introduction are very different. Local translocations have occurred within the Padano-Venetian district, and between the Padano-Venetian district and other parts of Italy and its larger islands. In the Padano-Venetian district there has been considerable importation of Danubian species to stock public waters. In the Tuscano-Latium district (central Italy) the fish fauna is now dominated by exotic species mostly introduced from the Padano-Venetian district. This process has caused the disappearance or decline of native species at many sites, especially from the main rivers. Three species are now endangered: one from northern and two from central Italy.

The brown trout (*Salmo trutta*) is native to Italy and has been translocated. The earliest recorded transfer of this species occurred around 1700.

BLANCO, G., E. CAGIGAS, E. VAZQUES and J. A. SANCHEZ. 1996. The use of genetic tag in the evaluation of fish restoration programmes. Presented at the Council Meeting of the International Council for the Exploration of the Sea, 27 September-4 October, 1996, Reykjavik, Iceland. 13 p.

The incidence of stocking programmes on natural populations of brown trout (*Salmo trutta)* in rivers of Navarra (northern Spain) was investigated using LDH-5* locus as a genetic maker. This locus is a useful marker because stock used in restocking these rivers are fixed for the LDH-5* 90 allele whereas this allele is not naturally present in wild populations of this area. Samples collected in stocked localities showed introgression rates ranging approximately from 0 to 50%. However these values, as well as the frequencies of LDH-5* 90 allele, decreased after the stocking practices were interrupted in these localities. These results suggest a very low viability of stocked individuals in natural conditions and the apparent failure of stocking programs which are to enhance the natural populations.

BLANCO, G., E. CAGIGAS, E. VAZQUES and J. A. SANCHEZ. 1998. Genetic impact of introduced domesticated strains of brown trout (*Salmo trutta*) on native Spanish populations. p. 371-379. *In* I. W. Cowx [ed.]. *Stocking and Introduction of Fish.* Fishing News Books, Blackwell Science, Ltd. MPG Books, Ltd. Bodmin, Cornwall, Great Britain.

Introgression between domesticated stocks and natural populations of brown trout was investigated using allozyme allele frequencies at the *LDH-5** locus. Fish samples were collected from the rivers in the Guipúzcoa and Navarra regions (northern Spain) from 11 undisturbed sites and 30 sites that have been continuously stocked over the past twenty years. In 3 unstocked sites, a mixture of native, hatchery and hybridized individuals were found, indicating movements of hatchery trout released in nearby stocked sites (1 to 5 km apart). Despite the long period of repopulation, only 77 out of 795 individuals caught in stocked sites were apparently of hatchery origin. In these stocked samples introgression rates ranged from 1 (in 8 out of 30 samples) to 34.8%.

These results show that stocking of domesticated strains resulted in genetic contamination of many Spanish populations without any major increase in population size. From a genetic conservation perspective it is recommended that Spanish natural brown trout populations are identified and protected by avoiding the use of foreign hatchery strains for stock enhancement.

BOHM, L. and P. W. BETTOLI. 1997. Assessment of a Tennessee trophy trout fishery. Presented at the 1997 Southern Division of the American Fisheries Society midyear meeting, San Antonio, Texas. (Abstract only)

The Clinch River below Norris Dam in east Tennessee supports a trophy trout fishery and is stocked annually with about 30,000 harvestable and 150,000 fingerling rainbow and brown trout. Between August 1995 and August 1996, seven different cohorts of fingerling and harvestable rainbow trout and brown trout were microtagged and stocked (N_{TOTAL}=46,000) over a 20 km reach of the river. Growth and survival of tagged trout were investigated by electrofishing 12 fixed transects each month and conducting a roving creel survey. Habitat was surveyed and mapped utilizing a modified version of the Basinwide Visual Estimation Technique. Fingerling rainbow trout and brown trout stocked in February-March 1996 grew well and were commonly collected through October 1996. The catch of tagged trout stocked late in the fishing season (June and August) approached zero substantially faster (40-80 days post-stocking) than the catch of tagged trout stocked in April (170 days). The rates of decline for each cohort of harvestable trout varied directly with the amount of fishing pressure the tailwater received. Trout abundance and average size varied among reaches of the river and were affected by differences in habitat and fishing pressure in different reaches of the river.

BOLES, H. D. 1960. Experimental stocking of brown trout in a California lake. Proceedings of the Annual Conference of Western Association of Game and Fish Commissioners 40 : 334-349.

Returns and angling success from planting different strains of brown trout and brown trout of the same strain with different periods of domestication were measured at Lower Sardine Lake, Sierra County. No fingerling group returned over 2.5% of the number planted.

All groups of catchable-sized brown trout were successful in providing stabilized fishing. Their extended return and survival ultimately gave a high ratio of weight returned over weight planted. Angling success was satisfactory when the planting density was adequate.

Catchable-sized brown trout from California wild spawners return slowly over a period of six years, with the smallest cumulative return (46%), but a return in weight about equal to that of the total fish planted. Stock from this same strain, after domestication for one or two generations, shows appreciable cumulative returns over a three year period (a total of 56% or more) greater than those from the wild stock.

Cumulative returns of eastern domestic strains, over a period of four years, compare favorably with California domestic rainbow stock (above 70%). They survive and grow far better in the hatchery than the lesser domesticated California brown trout stock and return from one and one-half to twice their rate during the first season planted.

Apparently, only a small portion of the brown trout at this lake become predominantly piscivorous. Most of the population subsists on insects and other food.

Their average size does not exceed 11 inches. The catchable-sized brown trout apparently compete satisfactorily with an existing sucker population, but there is no evidence that they have reduced the abundance of the suckers.

There are indications that the eastern strains mature at an early age.

Tests of different size groups of fish planted revealed that larger fish are caught earlier, give 18-20% higher return and, consequently, introduce error into the method of determining growth increments by averaging the monthly mean lengths of the catch.

BOLES, H. D. and D. P. BORGENSON. 1966. Experimental brown trout management in Lower Sardine Lake, California. California Fish and Game 52(3) : 166-172.

Seven years were spent studying various sizes and strains of planted brown and rainbow trout in this high elevation, oligotrophic lake. All fingerlings tested produced very low angling returns. Domesticated strains of catchable-sized browns equaled the best strains of domesticated rainbow trout in returns to anglers. Both rainbows and browns produced better angling returns when stocked early in the season than when stocked late in the fall. All stocked trout grew slowly and very few grew larger than 11 inches even after 4 or more years in the lake.

BORAWA, J. C. 1988. Comparison of half-wild and domestic brown trout fingerling introductions into south Appalachian streams. Federal Aid Project NC F-024-R-12. Study Number I, Final Report. North Carolina Wildlife Research Commission. Raleigh, North Carolina. 14 p.

Domestic and half -wild (domestic females x wild males) fingerling brown trout strains were stocked into six North Carolina and two Virginia streams, to compare their performance with respect to growth, condition, survival, and impact on non-trout species.

BORAWA, J. C. 1990. Field evaluation of domestic versus half-wild brown trout fingerling stockings. p. 72-78. *In* Trout: Committee of the Southern Division of the American Fisheries Society.

BORGESON, D. P. 1987. Fish stocking guidelines. Fisheries Management Report No. 11. Michigan Department of Natural Resources. Lansing, Michigan. 32 p.

The size of fish which is stocked will depend on the assemblage of fish already present in the system. Trout streams with little or no reproduction can be stocked with brown trout if it has been determined that the species has the potential for success. The trout should be planted as yearlings in the spring to produce a return to the angler late in the fishing season. It is also predicted that these fish will be better equipped to survive the winter than fall plants. Fingerling plants may be used in streams which are lacking in any major predatory species. If planting is intended in a waterbody dominated by non-trout species, chemical reclamation should be conducted prior to stocking. Fingerlings can be stocked immediately following treatment, with the notion that large fall fingerlings or yearlings should be planted thereafter.

The stocking of brown trout to create two-story fisheries can be successful when 7 inch yearlings are used. Yearlings have been known to produce exceptional nearshore and bay fisheries in Lakes Michigan and Huron. Specifically in Lake Michigan and in Lake Huron plants of 10,000 to 40,000 brown trout have given significant returns to the fishery. At least 500,000 brown trout are planted annually in the Great Lakes.

BORIEK, M. 1999. Sea run brown trout stocked. New Jersey Department of Environmental Protection's Division of Fish, Game and Wildlife. Trenton, New Jersey. [http://www.state.nj.us/dep/fgw/news/crnstk99.htm]

During the third year of a five-year program 31,575 8 inch sea run brown trout were stocked into the Manasquan River. It is predicted that the fish will migrate to sea and then return to create a new fishery. To date, only nine freshwater and five saltwater catches of these released fish have been caught.

BOUVET, Y. and J. M. CHACORMAC. 1986. An example and the problems of stocking fish in a high mountain lake (Lac du Brevent, 2127 m, French Alps). Sciences de L' Eau 5(1) : 85-100.

The Lac du Brevent is located 2127 m above sea level. It is characteristic of alpine lakes with its ice cover during eight months each year. This oligotrophic lake is stocked with *Salmo gairdneri, Salmo trutta, Salvelinus alpinus* and *Salvelinus fontinalis*. Sampling this population made it possible to assign the origin of the fish caught to stocking. None of the species seems to reproduce. All specimens caught were less than 5 years old. The mixing of the groups successively introduced increases the variance of the growth-weight relationship. The coefficients of condition of all the species decrease to very small values during the winter.

BRASCH, J. and W. NIEMUTH. 1951. Overwinter survival of hatchery brown trout in Sawyer Creek, Washburn County, Wisconsin. *In* Proceedings of the 13th Midwest Fish and Wildlife Conference, December 12-14, 1951, Minneapolis, Minnesota.

BREWIN, M. K., L. L. STEBBINS and J. S. NELSON. 1995. Differential losses of Floy anchor tags between male and female brown trout. North American Journal of Fisheries and Aquatic Sciences 15(4) : 881-884.

Annual loss of Floy anchor tags among brown trout (*Salmo trutta*) permanently marked by adipose fin removal, was studied in a population returning to spawn in three successive years (1988-1990) in a tributary of the Upper Bow River, Alberta. Significant differences were detected in tag losses between males (44.3%) and females (15.0%). Fork length distributions did not differ between trout retaining their tags and fish losing them or between fork length distributions of male and female brown trout that lost their tags. We speculate that higher tag losses among males may be caused by the biting of tags by other males during conflicts on the spawning grounds.

BRIDGES, C. H. and L. S. HAMBLY. 1971. A summary of eighteen years of salmonid management at Quabbin Reservoir, Massachusetts. p. 243-254. *In* G. E. Hall [ed.]. Reservoir Fisheries and Limnology. American Fisheries Society Special Publication No. 8. Bethesda, Maryland.

Quabbin is a deep, soft-water reservoir with two-thirds of the volume consisting of cold-water habitat. Three fisheries management programs have been implemented: trout-walleye, 1952-60; lake trout-brown trout-rainbow trout, 1957-1965; and lake trout-landlocked salmon, 1965-70. During the initial management program, walleye establishment failed. Lake trout and brown trout were the most successful in the second program. The lake trout and landlocked salmon program shows signs of success. Throughout the three programs, rainbow smelt abundance has fluctuated primarily due to a chemical control program instituted to reduce the population which was interfering with the water supply distribution system.

BROOKS, J. E. 2000. A new obstacle to recovery of Gila trout: Unauthorized stocking of non-native salmonids. Presented at the Year 2000 American Fisheries Society Annual meeting, August 20-24, 2000, St. Louis, Missouri. (Abstract only)

The Gila trout (*Oncorhynchus gilae*) is a rare salmonid restricted to headwaters of the Gila River basin of southwestern New Mexico and was recently re-introduced into Arizona waters. Stocking of non-native rainbow, cutthroat, and brown trout and catastrophic fire impacts contributed to the elimination of most relic populations. Recovery efforts for Gila trout since the early 1970s have centered around the removal of nonnative salmonids from selected streams above natural or manmade physical barriers and restocking with Gila trout. Public opposition to recovery efforts has increased in southwestern New Mexico and slowed stream renovations through implementation of the National Environmental Policy Act in opposition to the use of antimycin. Black Canyon, tributary to the East Fork Gila River, formerly supported populations of rainbow and brown trout. Stream habitat degradation related to historic grazing practices and wildfire in 1995 and 1996 eliminated these non-native species. A gabion barrier was constructed on Black Canyon during June 1998, with the planned stocking of Gila trout to occur in October 1998. Final stream surveys during late June 1998 to confirm absence of nonnative salmonids resulted in the collection of four brown trout, 70-74 mm total length, and one rainbow trout, 225 mm total length. Subsequent extensive field efforts sampled the entire upper Black Canyon drainage and resulted in the collection of 376 nonnative trout. We collected 345 young-of-year or age I brown trout, 24 adult rainbow trout, and 7 adult cutthroat trout. The absence of adult brown trout and young-of-year or juveniles rainbow and cutthroat trout, the absence of nonnative trout during 1996-1997 sampling and scale analysis of captured brown trout support our contentions of unauthorized introductions of non-native salmonids in 1998. Elsewhere, a population in Mogollon Creek was established after stream renovation and subsequent genetic analyses indicated that rainbow trout had been introduced into this population on two separate occasions, providing additional evidence for unauthorized stockings. Illegal stocking of nonnative salmonids presents a serious challenge to conservation efforts for Gila trout. Although improved public relations may help, increased law enforcement efforts are necessary to diminish the threat to extant populations of Gila trout.

BRYNILDSON, C. L. 1957. Comparative study of stocked rainbow and brown trout in Milner Branch, Grant County. Southern Area Investigational Memorandum No. 205. Wisconsin Department of Conservation. Madison, Wisconsin. 22 p.

BRYNILDSON, O. M. 1967. Dispersal of stocked trout in five Wisconsin streams. Fisheries Research Report No. 26. Wisconsin Conservation Department. Madison, Wisconsin. 9 p.

Brown trout stocked as fingerlings during early summer and during the fall remained near the stocking sites or dispersed upstream from the stocking sites by the following spring. Yearling brown trout released during January were distributed above and below the stocking sites but were concentrated at the stocking sites the following April. Out of six stocks of yearling brown trout released during March, four had greater dispersal downstream than upstream from the area of release and two had greater dispersal upstream than downstream a week to a month after release.

BRYNILDSON, O. M. and L. M. CHRISTENSON. 1961. Survival, yield, growth and coefficient of condition of hatchery-reared trout in Wisconsin waters. Miscellaneous Report No. 3. Wisconsin Department of Conservation. Madison, Wisconsin. 23 p.

BRYNILDSON, O. M., P. E. DEGURSE, and J. W. MASON. 1966. Survival, growth, and yield of stocked domesticated brown and rainbow trout fingerlings in Black Earth Creek. Fisheries Research Report 18. Wisconsin Department of Natural Resources. Madison, Wisconsin. 15 p.

Fall stocked fingerling brown trout had 51 to 90% survival to the following spring. Fall-hatched rainbow trout fingerlings stocked in the fall, had 42 to 60% survival to the following spring.

June-stocked fingerling brown trout had 13% survival to the following September. June-stocked fingerling fall-hatched rainbow trout had 26 to 30% survival to the following September, whereas 40% of the June-stocked winter-hatched rainbow trout fingerlings survived to the following September.

All stocks of rainbow trout had higher total weights in April than the total weights stocked the previous June or September. The highest gain in total weight from June to the following April was 894%. Out of five stocks of brown trout, 3 stocks weighed more the following April than when stocked the previous June or September.

All stocks of rainbow trout censused yielded more pounds of trout flesh to the creel the following fishing season than was originally stocked. None of the brown trout stocks yielded more pounds to the creel the following fishing season than was originally stocked.

BRYNILDSON, O. M., V. A. HACKER and T. A. KLICK. 1963. Brown trout: It's life history, ecology and management. Publication 234. Wisconsin Department of Conservation. Madison, Wisconsin. 15 p.

The rearing of brown trout in hatcheries is considerably more expensive than that of rainbow trout and for this reason there are few commercial brown trout hatcheries. Approximately one-third of Wisconsin's trout hatcheries rear brown trout. Most stocking is done on a put-and-take basis. Evidence has demonstrated that when summer or fall fingerlings are stocked in streams or lakes with moderately warm temperatures, low trout production and low numbers of adult trout, the stocking will be successful. Survival is low in the presence of predators and excess competition. The brown trout is a great competitor and for this reason is not planted into brook trout habitat. Brown trout are known to prey upon brook trout and to even become cannibalistic. Lake stocking, although successful in terms of survival often does little to contribute to the fishery given that they are not readily caught.

BRYNILDSON, O. M. and J. J. KEMPINGER. 1973. Production, food and harvest of trout in Nebish Lake, Wisconsin. Technical Bulletin No. 65. Wisconsin Department of Natural Resources. Madison, Wisconsin. 20 p.

In June 1967, stocks of 4,500 age 0 brown trout and 4,500 age 0 rainbow trout were stocked into Nebish Lake, a soft-water lake which had been chemically treated in 1966 to remove all resident fish. Relative production, growth, harvest and food of the two species of trout were compared for 4 ½ years after their release.

Rainbow trout had the higher production of the two stocks because they survived better and grew faster than the brown trout. Poundage of rainbow trout in the angler's catch during the first two years of fishing was higher than the total poundage of brown trout produced in the lake during the 4 ½ years. For each pound of brown trout and rainbow trout stocked, 5.2 and 15.0 pounds, respectively, were harvested by anglers.

Copepods were not found in the trout stomachs. *Daphnia*, 1 mm and larger, was the staple food of brown and rainbow trout less than 16 inches, whereas fish was the prominent food of larger trout.

After three years of grazing by trout and by a burgeoning population of yellow perch, three of four species of *Daphnia* disappeared from Nebish Lake and small *Bosmina longirostris*, which had not appeared in the Clarke-Bumpus samples before, became the dominant open-water cladoceran. After 4 years of grazing by perch, two species of *Daphnia* reappeared but in relatively low numbers.

Based on these data, it appears that trout growth can be rapid in a soft-water lake containing large species of *Daphnia* if the lake's production capacity is not taxed by large stocks of planktivorous fish.

BUDIHNA, N. and A. OCVIRK. 1990. Breeding and restocking of salmonid fishes in Slovenia. Journal of Fish Biology 37 (Supplement A) : 239-240.

Slovenia, in the north-west of Yugoslavia, abounds in waters. The Alpine, pre-alpine and karstic rivers of the Danube and the Adriatic River basin are populated by five native salmonids, among which the dominant species is brown trout (*Salmo trutta fario*) followed by lake trout (*S. t. lacustris*), grayling (*Thymallus thymallus*), huchen (*Hucho hucho*) and marbled trout (*Salmo marmoratus*). These fishes occupy about 1,907 ha of rivers.

The foremost purpose of artificial propagation of the above salmonids is to preserve populations whose survival is threatened for various reasons. Protection and conservation of fish species are put into practice by developing methods of artificial breeding and restocking, by creating reservations, enforcing biological requirements in the construction of hydroelectric power stations and supervision of existing populations of fishes. The entire enterprise is directed from a central institution, the Fisheries Research Institute at Ljubljana.

Restocking with brown trout, grayling and huchen dates back to the 1960s, whereas the restocking of marbled trout and lake trout began in the 1980s; methods for successful artificial breeding are still being researched. Marbled trout and lake trout are the two most seriously threatened fish species in Slovenia, marbled trout due to genetic "pollution" and lake trout due to overfishing.

In the case of brown trout and to a certain extent marbled trout, artificial breeding for restocking waters is extensive, performed in 495 ha of nursery streams. These annually receive 3 million brown trout fry and 130,000 marbled trout fry.

Lake trout, grayling and huchen are bred extensively at fish farms. Spawning fish are obtained from natural populations. Stock fish are kept for eggs and fry of marbled trout, grayling and huchen.

The results of the annual restocking of salmonid species in natural waters for the period 1984-1988 are shown, including a hybrid between *S. trutta* m. *fario* and *S. marmoratus*. This hybrid is unfortunately still present in the Adriatic basin and occupies third position in the catch statistics of angling.

The positive effects of restocking are evident from an average annual catch of 27,570 kg of salmonid fish or 14.45 kg/ha . In the annual catch, brown trout represents 59%, grayling 31%, the hybrid 6%, marbled trout 2% and huchen 2%. No data are available for lake trout.

BURROUGH, R. J. and C. R. KENNEDY. 1978$_a$. Interaction between perch (*Perca fluviatilis*) and brown trout (*Salmo trutta*). Journal of Fish Biology 13(2) : 225-230.

A decline in the growth rate of perch in Malham Tarn, Yorkshire, has occurred in recent times. This was found to coincide precisely with the resumption of stocking of brown trout, after a period of several years during which no stocking took place. In the absence of any other known correlating factor, it is suggested that the increase in population density of the trout may be responsible for the observed decline in perch growth.

BURROUGH, R. J. and C. R. KENNEDY. 1978$_b$. Observations on the brown trout (*Salmo trutta*) and perch (*Perca fluviatilis*) of Malham Tarn, North Yorkshire. Field Studies 4(5) : 631-643.

A survey, carried out from 20 to 27 July 1977, of the brown trout (*Salmo trutta*) and perch (*Perca fluviatilis*) in Malham Tarn is reported. Due to a stocking programme the virtually native trout population has recently been replaced by an almost wholly stocked population. For the trout details are given of growth, food and feeding, catches made by anglers in relation to the stocking of trout and the success of the stocking programme. Suggestions for the future management of the trout fishery are made. For the perch studies of age and growth and food and feeding are reported. The interactions between trout and perch are discussed.

BUSS, K. and R. McCREARY. 1960. Competitive survival ability of brook, brown and rainbow trout fingerlings in a stream-fed raceway. Progressive Fish Culturist 22(3) : 99-102.

Twenty thousand each of brook, brown, and rainbow trout were placed in an earthen raceway to test their ability to compete with one another with no artificial feeding or care. Forty percent of the rainbow trout survived, but most of these were in such an emaciated condition that their survival for another year is doubtful. Twenty-three percent of the brown trout were recovered, and most of these trout were in good condition. The brown trout may have suffered more from interspecific predation because they were initially the smallest of the three species planted. The surviving brown trout showed the greatest increase in growth. Also the brown trout was the only species which showed an increase in weight over that planted. The survival of brook trout was negligible, amounting to less than 0.1% of the 20,000 stocked.

It is felt that had this experiment been allowed to continue for another year, the brown trout would have been the predominant species, with the other two almost eliminated. One hundred and eighty-nine pounds of trout per acre-foot were maintained over a one year period in this environment.

BUTLER, D. W. 1975. Brown trout stocking study. Fisheries Report F-031-R-01. Texas Department of Parks and Wildlife. Austin, Texas. 16 p.

The objective of this study was to determine benefits generated from the stocking of fingerling brown trout (*Salmo trutta*) into an existing catchable rainbow trout fishery located in the Guadalupe River below Canyon Reservoir, Comal County, Texas. Electrofishing samples from April 1972 through August 1974 indicated brown trout fingerling survived in significant numbers for a few months after stocking, but survival beyond one year was low. Growth was rapid with fingerlings reaching a total length of approximately 120 mm after three months. The largest brown trout collected during the study measured 419 mm in total length and weighed 550 g. It was collected approximately 19 months after introduction. Random weekend and weekday creel surveys (October 1972 – May 1973; and February 1974 – January 1975) indicated low returns of brown trout (less than 1% of trout stocked). Total cost of brown trout stocking was $7,800, or $8.95 for each fish (817) returned to the fisherman. Low stocking rates, large water volume releases from Canyon Reservoir that kept fishing pressure light during 1974, and poor trout survival after 1 year were major factors affecting the harvest of brown trout.

CADWALLADER, P. L. 1983. A review of fish stocking in the larger reservoirs of Australia and New Zealand. Food and Agriculture Organization of the United Nations Fisheries Circular No. 757. Ministry for Conservation. Victoria, Australia. 37 p.

This is a review of stocking native and exotic fish species in Australian and New Zealand reservoirs. As sport fishery is the far dominant type of fishing activity on these water bodies, most effort has been spent on stocking salmonids. *Salmo gairdneri* and *S. trutta* have been the main species stocked in reservoirs in New Zealand and the cooler parts of Australia. In New Zealand, *S. gairdneri* are self-sustaining and form the basis for a major recreational fishery. Trout stocking aspects are dealt with in detail and alternatives to stocking with trout are suggested. More recently, there has been a tendency to preferentially stock native fish wherever ecological conditions allow. There is a great scope and potential for stocking indigenous fish, particularly in south-eastern Australia, but Queensland is at present the only Australian state whose reservoir stocking is now based entirely on Australian native fish.

CAGIGAS, M. E., E. VÁZQUEZ, G. BLANCO and J. A. SÁNCHEZ. 1999. Genetic effects of introduced hatchery stocks on indigenous brown trout (*Salmo trutta*) populations in Spain. Ecology of Freshwater Fish 8 : 141-150.

To assess the levels of gene introgression from cultured to wild brown trout populations, four officially stocked locations and four non-stocked locations were sampled for one to three consecutive years and compared to the hatchery strain used for stocking. Allozyme analysis for 25 loci included those previously described as providing allelic markers distinguishing hatchery stocks and native populations. Different levels of hybridization and introgression with hatchery individuals were detected in stocked drainages as well as in protected locations. These findings indicate that new policies for stocking and monitoring hatchery fish are needed if gene pools of wild Spanish brown trout populations are to be preserved.

CALIFORNIA DEPARTMENT OF FISH AND GAME. 1960. Lake basin investigations: Brown trout. Federal Aid Project F-8-R-9/SP2. California Department of Fish and Game. Sacramento, California. 137 p.

CARLANDER, K. D. 1969. Handbook of freshwater fishery biology volume one. Iowa State University Press. Ames, Iowa. 752 p.

Past studies have demonstrated that brown trout experience faster growth in alkaline waters than acidic waters and their growth is positively correlated with total dissolved solids (TDS).

CARLINE, R. F., T. BEARD, Jr. and B. A. HOLLENDER. 1991. Response of wild brown trout to elimination of stocking and no harvest regulations. North American Journal of Fisheries Management 11(3) : 253-266.

Spring Creek, Center County, Pennsylvania, has been heavily stocked with catchable-sized trout and managed with liberal harvest regulations until pesticide residues were discovered in resident fishes. Stocking was then eliminated and three years later (1982) a no harvest regulation was enacted though terminal tackle was not restricted. We describe changes in the populations of wild brown trout (*Salmo trutta*) and in the fishery 7 years after harvest was prohibited. Density of age 1 and older trout increased by 165% and biomass by 100% in the absence of stocking and harvest. Changes in size and age structure of the population, growth and numbers of brown trout longer than 350 mm (total length) were not consistent among four stream sections. When the stream was stocked, fishing pressure was high at the beginning of the season and declined rapidly thereafter. After stocking and harvest were suspended, fishing pressure was high throughout the season. Pressure ranged from 966 to 3,374 angler hours per hectare; 38% of the anglers used bait. Catch rates of trout increased from about 0.2 to 1.3 hr^{-1}. Among three stream sections the estimated numbers of trout caught and released during an 8.5 month survey period were 1.3 to 6.4 times the estimated population in July or August. We conclude that hooking mortality associated with bait fishing had to be relatively low for this fishery to support such high densities of brown trout and high rates of catch and release.

CHAMBERLAIN, T. K. 1943. Research in stream management in the Pisgah National Forest. Transactions of the American Fisheries Society 72 : 150-176.

Five years of experimental stream management with 150 miles of trout stream, divided between six watersheds, resulted, after various management practices were tried, in an increase of approximately 300% in anglers and in number of fish caught. After the first year, all hatchery fish were marked by fin-clipping before being planted. Recoveries from plantings made at different seasons showed a five-fold increase in recovery of spring planted legal-sized trout over trout of near equal size planted in the fall. Specifically, brown trout demonstrated a 0.7% recovery for the summer plant, 15.3% (average) for fall plants and 16% (average) for spring plants. During the last years of the experiment, emphasis was placed on stocking with legal-sized trout in the spring. Success indicates that this method is the best means of meeting increased fishing demand. Unfavorable practices, such as closing a stream to fishing every other year, were discontinued. Because of the requirement that a complete creel census be taken over wide-spread fishing areas with a limited personnel, a fishing schedule was evolved, staggering the open days for the different streams under an arrangement called "The Pisgah System." While the system permitted only one watershed to be opened at a time, it was found adequate to meet the increasing fishing intensity by spreading the fishing fairly evenly.

CHAMPIGNEULLE, A., M. MELHAOUI, D. GERDEAUX, R. ROJAS-BELTRAN, C. GILLET and J. GUILLARD. 1990. The brown trout (*Salmo trutta*) in the river Redon, a small tributary of Lake Leman. I – Characteristics of river dwelling trout during the years 1983-87 and first data on the contribution of stocked pre-fed fry. Bulletin de la Pêche et de la Pisciculture 319(4) : 181-196.

This paper presents the characteristics (density, apparent mortality, growth) of resident brown trout (*Salmo trutta*) juveniles, in a small (10 km) tributary of Lake Leman (58,240 ha) from 1983 to 1987. The study was conducted to distinguish the "natural recruitment" from restocking (2 origins: hatchery and lake dwelling spawners). The study indicates the efficiency of restocking with pre-fed fry (3-4 cm) on the juvenile (0+, 1+) population level in the tributary.

CHAMPIGNEULLE, A., M. MELHAOUI, D. GERDEAUX, R. ROJAS-BELTRAN, C. GILLET, J. GUILLARD and J. P. MOILLE. 1990. The brown trout (*Salmo trutta*) in the river Redon, a small tributary of Lake Leman. II – Characteristics of lake dwelling trout spawners during the years 1983-88 and first data on the contribution of stocked pre-fed fry. Bulletin de la Pêche et de la Pisciculture 319(4) : 197-212.

This paper presents the characteristics (age, growth) of lake dwelling brown trout (*Salmo trutta*) spawners sampled during 5 consecutive years in the River Redon, a small tributary (10 km) of Lake Leman (58,240 ha). The young spawners of 2-3 years represented 73% of males against only 33% of females. Scale examination indicated the occurrence of 1 year (56%), 2 years (43%) or 3 years (1%) of slow "river type" initial growth. The back calculated total length at one year was significantly higher for spawners of type 1 (129 mm) than for spawners of type 2 (100 mm). A batch of 6,000 fry (4 cm) pre-fed in the hatchery, issued from lake dwelling trout spawners, was marked and stocked in August 1983 in the downstream part of River Redon. The lake dwelling trout spawners issued from this small batch represented an important part (46% of females and 22% of males) of the corresponding adult cohort spawning in the River Redon.

CHELKOWSKI, Z. 1990. Biological characteristics of one-year-old sea trout (*Salmo trutta*) grown fry released into the Stream Osowka. Acta Ichthyologica et Piscatoria 20(1) : 45-58.

In the spring of 1982, the fry of sea trout (*Salmo trutta*) were released into the Stream Osowka. The fish were caught by electrofishing after 8-11 months. The paper presents survival and dispersion of the young sea trout as well as data on length, weight, growth and condition of retrieved fish.

CHELKOWSKI, Z. 1991. Survival rate of sea trout (*Salmo trutta*) from hatch release to smolting in the Stream Osowka. Acta Ichthyologica et Piscatoria 21(1) : 93-98.

In the spring of 1984, 5,402 sea trout hatchlings were released into the upper section of the Osowka Stream. In three subsequent years after release smolts were caught with a trap located downstream the release site. The number of smolts caught allowed the survival rate over the period from hatch release to smolting to be determined.

CHELKOWSKI, Z. 1992$_a$. Sea trout (*Salmo trutta*) and salmon (*Salmo salar*) catches in the Lower Odra River system as well as stocking in the years 1973-1987. Acta Ichthyologica et Piscatoria 22(2) : 123-147.

The paper presents and analyzes catches of sea trout and salmon in the lower Oden River system during the period of 1973-1987. Both of the fish species had to be treated jointly for complying with the economic statistics, having been the source of information concerning the catches. The variations of catches were taken into account with regard to years, months as well as regional division. Moreover data were accumulated as to the stocking of the lower Oden water system with sea trout and salmon during the period of studying the catches.

CHELKOWSKI, Z. 1992$_b$. Biological characteristics of sea trout (*Salmo trutta*) smolts of known age from Osowka Stream. Acta Ichthyologica et Piscatoria 22(2) : 107-122.

In the spring of 1984, sea trout larvae were released into the upper stretch of Osowka Stream. The grown smolts were caught in three consecutive years after the fish release, using a fish trap placed in the middle course of the stream. The fish were used to determine fish sex and sex ratio, gonad condition and development, length and weight of males and females; and condition of sea trout smolts of known age.

CHELKOWSKI, Z. 1995. Biological characteristics of sea trout (*Salmo trutta*) smolts grown from fry and released in the Stream Osowka. Acta Ichthyologica et Piscatoria 25(1) : 19-33.

In the spring of 1987, the fry of sea trout (*Salmo trutta trutta*) were introduced into the upstream of Osowka. Smolts grown from this material were caught during three successive years after the fish release, with the aid of a fish trap situated in the middle course of the stream. Sex, condition and coefficient of gonad development, as well as length, weight and factor condition of smolts of the known age were determined.

CHRISTENSON, L., V. HACKER and O. BRYNILDSON. 1954. Does fall trout stocking pay? Wisconsin studies give us some more facts about the angler's catch of spring- and fall- stocked trout. Wisconsin Conservation Bulletin 19 : 15-17.

Two streams, Willow Creek and Rocky Run Creek were used in brown trout stocking experiments. Both are known as high quality trout streams. Brown trout were planted in the spring and the fall to determine which season gave the best returns. Of those stocked on Willow Creek, spring-stocked fish out numbered fall-stocked fish 7:1 in the anglers' return. At Rocky Run Creek, the ratio was 5:1. Interestingly, when the streams were electrofished there were two spring-stocked brown trout for each fall-stocked brown trout. It appears that the fall-stocked fish are not being caught in proportion to their abundance.

CHRISTIE, W. J., J. M. FRASER and S. J. NEPSZY. 1972. Effects of species introductions on salmonid communities in oligotrophic lakes. Journal of the Fisheries Research Board of Canada 29 : 969-973.

Adequate documentation was often wanting for interpretation of conditions surrounding the success or failure of an exotic. There was also known differences in species composition and other circumstances which made comparisons between SCOL lakes difficult.

Successful colonization appeared possible where a sufficiently plastic new species found a niche either temporarily or permanently void. The lack of normal ecological constraints favored the explosion of a colonist, and examples were found which indicated both physiological and behavioral adaptation to permit establishment. The data suggested predation may be important in suppressing invaders. The higher diversity of littoral fish communities provided greater resistance to colonists. The role of exploitation in the fate of any colonist seemed chiefly in its effect on diversity and on stock oscillations. Eutrophication favored the success of colonists through continued destabilization of communities. It was suggested that management should proceed towards greater diversity to minimize the chances of outbreaks of pest fishes.

Some species are able to simply assume whichever vacant niche is available. The introduction of the brown trout (*Salmo trutta*) has been greatly successful because they are able to adapt to such a wide range of environmental and biological conditions.

COBB, E. W. 1933. Results of trout tagging to determine migrations and results from plants made. Transactions of the American Fisheries Society 63 : 308-318.

Brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were tagged before release in order to get an idea as to the results from the previous seasons planting. The total number of streams stocked with tagged trout and on which records were kept was thirty-five.

Taking, as an example, streams in which were planted 4,429 tagged brook trout and 4,250 tagged brown trout, we found that of the entire lot 2,713 or 31 percent were taken. The percentage of the total plant of brown trout caught was about two-thirds as great as the percentage of brook trout. Of the entire catch, 75.5 percent were caught in the section where planted, 6.5 percent had moved upstream, 14.5 percent had moved downstream and 3.5 percent had moved into tributaries.

A comparison of the movements of brook and brown trout in four streams in which both species had been planted shows the following results. Taken in the section in which planted, brook trout were 79.7 percent and brown trout were 66.5 percent. Upstream, brook trout were 6.9 percent and brown trout were 6.8 percent. Downstream, brook trout were 9.1 percent and brown trout were 26.6 percent. In tributaries, brook trout were 4.3 percent and brown trout were 0.1 percent. This tends to prove the correctness of our idea that our brown trout should be planted where a run downstream will place them in a good body of water rather than in a polluted stream. It also tends to show that the brown trout has no great tendency to go to the smaller and colder waters above which are in many instances inhabited by brook trout and utilized by them as a breeding ground.

COLES, T. F. 1981. An analysis of the put-and-take fishery at Toft Newton Reservoir. Fisheries Management 12(4) : 129.

The operation of a put-and-take trout fishery at Toft Newton reservoir is analysed from detailed studies of the 1978 and 1979 seasons. Toft Newton is only a small reservoir but the large number of anglers that utilize the fishery mean that the stocking rates per hectare of water have to be very high. As a result of these high densities and a short average residence time in the reservoir, rainbow trout which were the predominantly stocked species, do not grow after release. Brown trout, however, which were stocked at lower densities do grow after release. The success rate of the 8-9% of anglers not returning their catch data was examined using a postal survey. Partial correlation analysis indicated that the numbers of fish in the reservoir, the number of anglers fishing and the number of hours of sunshine significantly affected the catch rate. A regression between catch rate and number of fish in the reservoir only explained 35% of the variability but the addition of the other two factors did not significantly improve the accuracy of the model. The market area of the fishery was studied from the register of anglers. Most anglers attending Toft Newton travel a considerable distance to the fishery, the peak number driving from 98-129 km (61-80 miles) round trip. The present and future management policy of the fishery is discussed in the light of this analysis and many of the recommendations may also apply to other small put-and-take trout fisheries.

COOPER, E. L. 1952. Returns from plantings of legal sized brook, brown and rainbow trout in the Pigeon River, Ostego County, Michigan. Transactions of the American Fisheries Society 82 : 265-280.

A complete census of fishing on 4.8 miles of the Pigeon River together with population estimates made at the end of the open season made possible an accurate evaluation of the yield and survival of open season plantings of hatchery trout. Fishing intensity in this research area for three years averaged 2,414 daily trips per year which was equivalent to 278 hours of fishing effort per acre per year. Sections in which hatchery fish were planted attracted about three times as much fishing as did the unplanted sections. Fishing quality, measured by the catch-per-hour-per-fishing trip, was generally poor for native fish averaging less than 1 fish for 5 hours of effort. Hatchery fish made up for about 70% of the total catch for 3 years.

Planting trout from a live crate a few at a time (scatter planting) did not prove to advantageous over the practice of liberating large numbers of fish in one hole (spot planting). Trout that had been scatter planted did not contribute to the catch for a longer period of time and produced fewer successful fishing trips, fewer total fish returned to anglers and slightly fewer anglers sharing in the total catch. However, the practice of making several plantings on different dates, a few fish at a time, permitted more individual anglers to share in the catch.

Although 4,500 legal-sized trout were planted each year, about half of the fishing trips were unsuccessful. Limiting the daily catch to 5 trout, instead of 15, did very little to reduce the percentage of unsuccessful anglers. Further reduction to 2 fish per day lowered the unsuccessful fishing trips to 36%.

Plantings of rainbow trout and brook trout gave much higher returns to the fishermen that did equal numbers of brown trout. Rainbow trout also survived over-winter as well as did brown trout, although in both species the survival was less than 10%. Over-winter survival of brook trout was less than 3%. Fin clipped trout were recovered by fishermen more readily than those which were jaw tagged. This difference was especially apparent during the first week following planting.

Rainbow trout and brook trout, planted when water temperatures were below 50° F exhibited an immediate downstream movement. Fish planted when water temperatures were above 50° F showed very little movement.

Legal sized brook, brown, and rainbow trout planted in a stream subjected to heavy fishing pressure contributed to the catch for a relatively short time. Brook trout were exploited most readily; only 4% of the recoveries were taken after 40 days of liberty. For brown trout and rainbow trout these values were 26% and 22% respectively. Planting large numbers of hatchery fish (up to 431 trout per mile) apparently had no effect upon the catch of wild fish in the stream. Although the catch-per-hour of the planted trout increased greatly at the time of planting, the corresponding weekly data on catch-per-hour of the wild trout showed no similar increase.

COOPER, E. L. 1953. Mortality rates of brook trout and brown trout in the Pigeon River, Ostego County, Michigan. Progressive Fish Culturist 15 : 163-169.

A 4.8 mile section of the Pigeon River is currently used to study the ecology of brook and brown trout. This specific project deals with the mortality rates of planted trout. In October 1951, 300 hatchery brown trout fingerlings were fin-clipped and planted into section C of the study area. Brook trout were also planted. Results showed that brown trout experienced higher survival rates than brook trout and that wild trout experience greater survival than hatchery-reared trout. The survival rate for hatchery brown trout was 22.0% and that for wild brown trout 41.9% over the study period of approximately one year.

COOPER, E. L. and N. G. BENSON. 1951. The coefficient of condition of brook, brown, and rainbow trout in the Pigeon River, Ostego County Michigan. Progressive Fish Culturist 13(4) : 181-192.

From April 1949 to October 1950, weight and length data was used to determine coefficients of condition on various trout species. Comparisons were made between wild and hatchery trout. It was discovered that brown trout from rearing ponds had different size ranges (8.1-12.5 inches) than those from Pigeon River (6.9-18.5 inches) and a smaller coefficient of condition (1.56 versus 1.62).

Of those hatchery brown trout planted in 1949 (total number 1,500), 25.6% were recovered in 1949, compared with only 2.2% in 1950. Comparisons of fish condition were made prior to and following stocking. It was determined that coefficient of condition dropped an average of 0.10 (1.64 to 1.54) during the first week of the fishing season.

COOPER, J., J. E. CRAWFORD and T. HECHT. 1992. Introduction and extinction of brown trout (*Salmo trutta*) in an impoverished subAntarctic stream. Antarctic Science 4(1) : 9-14.

Brown trout were introduced to the Van den Boogaard River on subantarctic Marion Island in 1964, and a small population became established. The last individual was seen in 1984, and the species is now considered to be extinct on the island. Their diet was exclusively allochthonous, with snails and spiders predominating. Ages were estimated at six to eleven years and showed that spawning must have occurred since the original introduction. Since the Van den Boogaard River enters the sea via a waterfall, it is postulated that trout were not able to practice an anadromous life-style, and that this, as well as other factors connected with the impoverished nature of the stream, led to dwarfing of the resident population. No further introductions of alien fish to Marion Island should be contemplated.

COPLEY, H. 1940. Trout in Kenya colony Part I – Brown trout. East African Agricultural Journal 5(5) : 345-361.

CORTES, R. M. V. 1996. Introducing brown trout (*Salmo trutta*): Consequences for stocked and native populations. Publicationes Especiales, Institutio Espanol de Oceanografia 22 : 269-274.

Brown trout (*Salmo trutta*) restocking is a common technique in fisheries management, and it is widely used in Portuguese fast-flowing streams, but without adequate assessment of its consequences. We released age 1+ hatchery-reared trout in a headstream with two purposes: to determine their spatial distribution, and to assess the interactions between the introduced individuals and the native trout population. Results showed two distinct features: (a) Total trout density and biomass did not significantly change, (b) native population was impacted (mainly year classes greater than or equal to age 2+) and, in addition, stocked trout presented a notorious contagious distribution which remained very intense during the first months. We conclude that the very different effects following this operation depend on the biological or physical factors controlling local populations. However, stocking success is strongly limited in space and time.

COUSINS, D. C., T. F. COLES and A. P. CRUST. 1981. A computer program for the analysis of catch returns from a put-and-take trout fishery. Fisheries Management 12(4) : 119.

This paper describes a computer program for the analysis of catch returns from put-and-take fisheries that can be operated by personnel with minimal computer training. The program was developed for the Toft Newton fishery in Lincolnshire and the method of collecting the data is illustrated. The advantages of using computer analysis for assessing the state of a fishery are outlined. A completed listing of the program can be obtained from the authors.

COWX, I. G. 1994. Stocking strategies. Fisheries Management and Ecology 1 : 15-30.

Stocking, transfer and introduction of fish are commonly used to mitigate loss of stocks, enhance recreational or commercial catches, restore fisheries or to create new fisheries. However, many stocking programmes are carried out without definition of the objectives or evaluation of the potential or actual success of the exercise. This paper describes a strategic approach to stocking aimed at maximizing the potential benefits. A protocol is discussed which reviews factors such as source of fish, stocking density, age and size of fish at stocking, timing of stocking and mechanism of stocking. The potential genetic, ecological and environmental impacts of stocking are described.

CRAWFORD, S. S. 1997. A review and ecological evaluation of salmonine introductions to the Great Lakes. Report prepared for the Chippewas of Nawash First Nation. Guelph, Ontario. 282 p.

Brown trout are native to west Asian and European waters. The species first arrived in North American waters between 1883-1884 when eggs were shipped to the United States. Brown trout were first introduced into the Great Lakes basin by the Americans in 1883 when Michigan stocked the Lake Michigan tributary the Pere Marquette River. That year fish were also introduced into a tributary of Lake Ontario. At this time many European and Asian strains such as the sea trout, the Swiss lake trout, the Loch Leven trout, the German trout and the Ohrid trout were introduced by the United States into each of the Great Lakes. Shortly after their arrival the distinction between the various strains was lost during artificial propagation. Although anglers were originally skeptical of the introduction of brown trout into the Great Lakes, the idea became accepted because of their proven ability to survive in water conditions where other species could not.

CRESSWELL, R. C. 1981. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters – A review. Journal of Fish Biology 18 : 429-442.

The success of stocking with hatchery-reared trout has been the subject of varied investigations for the past half century. Percentage returns are summarized and literature on the post-stocking movements of hatchery-reared trout are reviewed. Factors affecting the post-stocking movements are considered, special attention being paid to studies on industrial rivers. Highest returns are obtained from stockings with trout of a size suitable for angling made during or shortly before the angling season. The majority of stocked brown trout (*Salmo trutta*) tend to remain close to the area of stocking but brook trout (*Salvelinus fontinalis*) and rainbow trout (*Salmo gairdneri*) show greater movement, usually in a downstream direction. Greater dispersion of all species occurs if they have overwintered prior to capture or have been stocked in "cold water" or in small upstream stretches of river.

CRESSWELL, R. C. 1989. Conservation and management of brown trout (*Salmo trutta*) stocks in Wales by the Welsh Water Authority. Freshwater Biology 21(1) : 111-123.

The diversity, value and status of the trout resource within the Welsh Water Authority area is described.

Reported angling catches of sea trout have increased in recent years but there is an apparent decline in brown trout stocks. Factors affecting the distribution, status and diversity of the trout resource are identified and discussed.

Investigations are being carried out to evaluate the apparent problems and to provide information required to formulate management solutions. A management strategy is proposed which allows for the maintenance and development of the resource whilst ensuring the preservation of strains of trout which have conservation value in their own right.

Suggested methods for rehabilitation of the species include habitat protection, controlling exploitation and stocking. In 1977-78, 71,000 brown trout (7-25 cm) were stocked into Welsh rivers, yet this may be detrimental to the genetic integrity of the native population and there exists little long term benefit in supplemental planting.

CRESSWELL, R.C., G. S. HARRIS and R. WILLIAMS. 1982. Factors influencing the movements, recapture and survival of hatchery-reared trout released into flowing waters and their management implications. European Inland Fisheries Advisory Commission Technical Paper 42 (Supplement 1) : 129-142.

The success of stocking with hatchery-reared trout has been the subject of various investigations for the past half century. Percentage returns and post-stocking movements are summarized and related to the size and species of trout stocked and the season of stocking.

Factors influencing the movements, recapture and survival of hatchery-reared brown trout (*Salmo trutta*) stocked into rivers in Wales, U. K., were investigated during the period 1975-78. Experiments involved stocking more than 10,000 individually tagged trout, many of which had been acclimated to specific conditions. Information regarding the subsequent distribution of stocked fish was obtained from electrofishing surveys, trapping and tag returns by anglers.

The majority of stocked trout moved only short distances generally less than 1 km and principally in a downstream direction. The degree of dispersion after stocking was largely dependent on the character of the receiving river; dispersal was most extensive in fast-flowing rivers and more limited in deeper, more slow-flowing waters. Acclimation to flowing water prior to release had little effect on the distribution of stocked fish but did result in their being recovered in greater numbers. The presence of a resident wild population affected neither stocked fish movement nor their percentage recovery. "Spot- and scatter-planting" caused no difference in post-stocking movements but "spot-planting" did result in a higher percentage recovery.

Tag returns from stocked trout ranged from 10 to 62%. More than 65% of the stocked fish caught were taken within five weeks of stocking and more than 50% by less than 20% of the anglers benefiting. Less than 1% of the fish stocked contributed to the catch in the season after stocking.

The majority of stocked trout did not begin feeding until several weeks after stocking. The food intake of these fish tended toward that of wild trout as their period of residence in the river increased, but most stocked trout still had a lower food consumption after 40 to 50 days in the river. Many fish lost condition, reducing their chance of survival over the winter period. Hatchery-reared trout retained their distinctive silvery appearance for 2-3 months after stocking, making them more conspicuous to predators.

The implications of these findings are discussed in relation to expediency, efficiency and cost-effectiveness of future management strategies involving the stocking of hatchery-reared trout.

CRESSWELL, R. C. and R. WILLIAMS. 1979. Studies on trout stocking in an industrial river and their management implications. p. 285-295. *In* Proceedings of the 1st British Freshwater Fisheries Conference, 10-12 April, 1979, University of Liverpool. Liverpool, England.

Hatchery-reared brown trout (length 240-280 mm) were released during March-July, 1978 into the River Sirowy, a small river in South Wales, polluted by coal wastes and containing a low resident population of brown trout. Information regarding the movements and survival of the stocked fish was obtained by electrofishing, trapping and from anglers' returns which ranged from 11-64%. More than 69% of the stocked fish caught were taken within 4 weeks of stocking and more than 50% by less than 20% of the anglers benefiting. The majority of trout stocked moved only short distances (< 1 km), principally in a downstream direction. The management implications of these findings are discussed.

CRESSWELL, R. C. and R. WILLIAMS. 1982. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters: Effect of time and method of stocking. Fisheries Management 13(3) : 97-102.

Hatchery-reared brown trout (*Salmo trutta*) (length 23-26 cm) were stocked in the Afon Taf, South Wales. The effects of 'spot' and 'scatter' planting and of stocking at 1 and 4 weeks prior to the start of the angling season were investigated. Data on the percentage recapture and post-stocking movements of the trout were obtained from tag returns. Higher percentages were recorded for 'spot plantings' (65% and 31%) than for 'scatter plantings' (16%). Stockings made 1 week before the start of the angling season yielded better returns (17.1%) than those made 3 weeks earlier (2.2%). Neither 'spot' nor 'scatter planting' resulted in stocked fish contribution to the catch for an appreciably longer period of time. The majority of trout stocked were caught in the area of stocking irrespective of the method or time of planting.

CRESSWELL, R. C. and R. WILLIAMS. 1983. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters: Effect of prior acclimation to flow. Journal of Fish Biology 23(13) : 265-276.

Hatchery-reared brown trout (*Salmo trutta*) (Fork Length 16-27 cm) were stocked into the Afon Clettwr, Afon Western Cleddau and Afon Dysynni, Wales. The effects of (a) retaining fish caged in the river 24 hours before release, and (b) a period of acclimation to flowing water (up to 0.24 m/s) in tanks prior to stocking were investigated. Data on percentage recapture and post-stocking movements were obtained from trapping, electrofishing and tag returns. In-stream acclimation resulted in a higher percentage recapture and a more limited dispersion of the fish stocked under low river flow conditions, but had no effect on trout stocked into a river where higher water velocities were experienced. Acclimation, in tanks, to a flow of 0.1 m/s for 14 days led to higher percentage recaptures, whereas acclimation for only 2 days resulted in fewer returns than for unacclimated fish. No differences in fish distribution within the rivers could be attributed to these acclimation procedures.

CRESSWELL, R. C. and R. WILLIAMS. 1984. Post-stocking movements and recapture of hatchery-reared trout released into flowing waters – Effect of a resident wild population. Fisheries Management 15(1) : 9-14.

The post stocking movements and survival of hatchery-reared brown trout (*Salmo trutta*) (length 18-19 cm) stocked into depopulated and controlled stretches of the Afon Clettwr, South Wales, were investigated. Data were obtained from electrofishing surveys and rewarded tag returns.

Recapture rates ranged from 67-76% for both stretches. The resident population of wild brown trout had no significant effect on the dispersion of the stocked fish, the majority of which remained close to the point of stocking.

No stocked fish were recovered from the experimental stretches in the year following their introduction. Within one year the depopulated stretch had been recolonized by wild trout. The implications upon restocking after a fish kill are discussed.

CRISP, D. T. 1996. Experimental studies on planting artificial stream channels with unfed and six week-fed salmon (*Salmo salar*) and trout (*Salmo trutta*) fry/parr. Ecology of Freshwater Fish 5 : 68-75.

Experimental comparisons were made between release as unfed fry and release as six week fed parr, upon the growth and final population density of young salmon and trout over a ten week period. Salmon and trout released into experimental channels as unfed fry at densities of about 19 fish m^{-2} showed rapid reduction in numbers, chiefly by downstream dispersal accompanied by negligible growth. After substantial reduction in numbers, there was a reduced rate of dispersal and rapid growth. Salmon and trout retained in a hatchery at high density (80 to 200 fish m^{-2}) and fed for six weeks on proprietary food showed slow, but measurable, growth. After release into the channels these fish adjusted their numbers, mainly by downstream dispersal, and showed an increased growth rate. At the end of a ten-week period, salmon introduced as fed parr had approximately twice the population density of salmon introduced as unfed fry. No similar difference in population density could be shown for trout. For both species, the fish introduced as fed parr had a lower mean weight after ten weeks than had the fish introduced as unfed fry.

CRISP, D, T. 2000. Trout and salmon. Fishing News Books, Blackwell Science Ltd. Cambridge, England. 212 p.

If eggs are used for stocking purposes then mechanical shock should be minimized. Therefore, when stocking eggs in artificial redds, transportation should take place after eyeing, when sensititvity is less than at the "green" stage.

CRISP, D. T. and R. H. K. MANN. 1977. A desk study of the performance of trout fisheries in a selection of British reservoirs. Fisheries Management 8(4) : 101-119.

Routine statistics have been analysed from a varied selection of 18 British reservoir fisheries. The numbers and weights of fish caught have been compared with the numbers and weights stocked.

In lowland reservoirs, the "put-and-take" system of management is used and annual stocking rates of 40-60 fish ha^{-1} (12 kg ha^{-1}) give catches of 20-30 fish ha^{-1} (20 kg ha^{-1}). Higher stocking rates lead to greater catches numerically but to relatively little increase in the weight of catch-per-unit area. In general, the recapture of rainbow trout is greater than that of brown trout, relative to the numbers stocked.

The management of upland reservoirs is complicated by the presence of indigenous trout, poorer growing conditions and lack of research into the population dynamics of fish populations in such places. A wide variety of management possibilities exist in upland reservoirs and these are worthy of thorough investigation. Stocking at rates comparable to those used in lowland reservoirs takes negligible advantage of the potential for natural trout growth in upland reservoirs and the economics of this practice would benefit from closer analysis.

CROSSMAN, E. J. 1984. Introduction of exotic fishes into Canada. p. 78-101. *In* W. R. Courtenay, Jr. and J. R. Stauffer, Jr. [eds.]. Distribution, Biology and Management of Exotic Fishes. John Hopkins University Press. Baltimore, Maryland.

In the late 1800s the importation of exotic fish became a popular method to enhance Canadian fisheries. Only Prince Edward Island and the Northwest and Yukon territories have never, by definition, released or introduced any exotics.

The brown trout was introduced into other parts of Canada as a sport fish in order to please the anglers.

Manitoba remains the only province to continue to stock brown trout. This species was introduced throughout Canada between the late 1800s and the early to mid-1900s. In the easterly provinces there have been complaints of the brown trout displacing populations of native salmonids and only yielding low angler success. Other areas report no negative impacts with the exception of anglers finding the species difficult to catch. In Ontario the fish were extensively stocked between 1913 and 1918 and again around 1930 and it is thought that the brown trout have restricted the range of brook trout to the upper reaches of rivers. In Manitoba there has only been limited success with the establishment of brown trout populations. The dominance of northern pike in many lakes, along with winterkill conditions has led to the failure of brown trout.

CURTIS, B. 1951. Yield of hatchery trout in California lakes. California Fish and Game 37(2) : 197-215.

This paper brings together information obtained over 10 years from hatchery trout yield experiments on nine California lakes, of which six are considered primary and three of secondary importance. Most of these lakes have no or insufficient natural spawning. It is emphasized that lakes produce very different results from streams.

The results of the different projects vary widely. From fingerling plants, three large lakes (800 acres and up) produced low yields in comparison with three small lakes (33 to 68 acres). Average yield from the former was 1% with a range of 0.2 to 1.5; from the latter 8.7% with a range of 2.7 to 25.3. In all combined, fingerling plants averaged a yield of 5.4%. Specifically, brown trout fingerlings stocked between 1938 and 1945 only show a catch record return of 4.8% (over five years) in Castle Lake, a 32% yield for yearlings over two years in Castle Lake and a 7.7% yield of fingerlings in Frog Lake (over ten years). There was no evidence of brown trout spawning in Frog Lake.

Extraordinary improvement in yield from fingerling plants occurred in one 47 acre lake when a population of three planted trout species (brook, rainbow and brown) plus resident lake trout (mackinaw) was eliminated and replaced by one species.

Plants of catchable trout in seven lake experiments in which areas ranged from 10 to 800 acres gave an average yield of 44.9% with a range of 27.4-71.6%.

It is suggested that the arithmetic average yields of 5.4% from fingerlings and 44.9% from catchable trout take too little account of the variations in the reliability of the figures from which they are formed, and of the nonquantitative factors involved. Knowledge and consideration of these lead to the proposal that the figures which best interpret the results obtained in these experiments are: yield from fingerling plants (in lakes under 80 acres), 4%; yield from plants of catchable fish, 50%.

DAHLBERG, M. D. and D. C. SCOTT. 1971. Introductions of freshwater fishes in Georgia. Bulletin of the Georgia Academy of Science 29(4) : 245-252.

The brown trout is native to Europe and has been introduced into the mountain streams of Georgia. Although some natural reproduction does occur, this is mainly a put and take fishery. Mountain impoundments are also home to stocked brown trout which commonly contribute to second story fisheries. Currently there are attempts at establishing brown and rainbow trout fisheries in lakes Lanier, Hartwell and Clark Hill.

DAMSGAARD, B. 1995. Arctic charr (*Salvelinus alpinus*) as prey for piscivorous fish – A model to predict prey vulnerabilities and prey size refuges. Nordic Journal of Freshwater Research 71 : 190-196.

To study if stocking of piscivorous fish such as brown trout (*Salmo trutta*) can be used to regulate density and growth in slow growing populations of Arctic charr (*Salvelinus alpinus*) I used simple models to predict maximum prey length and relative prey vulnerabilities based on the gape sizes of predators, and body depths of prey. Brown trout had larger relative gape size than Arctic charr (8.8 and 7.5% of total length), but neither of them selected prey sizes up to gape limitation. Assuming a random encounter between predators and prey, the probability of being eaten for prey of a particular size is the product of the relative vulnerability and the relative frequency of occurrence. In a full-scale experiment with piscivorous brown trout, the model revealed an increase in the number of Arctic charr in prey size refuges. Furthermore, this method can be used to predict the effects of piscivorous predation in multispecies lakes, and regulate fishing to protect large piscivorous fish.

DAMSGAARD, B. and A. LANGELAND. 1994. Effects of stocking of piscivorous brown trout (*Salmo trutta*) on stunted Arctic charr (*Salvelinus alpinus*). Ecology of Freshwater Fish 3 : 59-66.

To study the effects on a stunted freshwater population of Arctic charr (*Salvelinus alpinus*), two groups of large (26-45 cm) individually tagged brown trout (*Salmo trutta*) were released and recaptured with gillnets after 1, 7, 11 and 63 weeks. One group of trout was trained on a fish diet before release and the other, reared on commercial dry pellets, served as a control. Specific growth rates in both groups were negative one week after release and approached zero after 63 weeks. Condition factor and internal fat content decreased during the experiment. Although only 11% of the trout stomachs examined contained fish prey, charr represented 79% of the total stomach weight content. Gill net samples of charr before and 63 weeks after the release of trout indicated a decreasing population size of charr. Individual growth and mean length of charr increased after release of trout, especially for charr at age 4 years. After the release of trout, 35% of the charr were longer than 20 cm as compared with 6% before the release.

DAVIES, P. E. and R. D. SLOANE. 1980. Long-term changes in brown trout and rainbow trout populations in Great Lake, Tasmania. North American Journal of Fisheries Management 8(4) : 463-474.

Great Lake, central Tasmania, was first stocked with brown trout (*Salmo trutta*) in 1870 and with rainbow trout (*Oncorhynchus mykiss*) in 1910; both species established self-supporting populations. Angling statistics revealed a general decline in mean weight of both species from 1892 (brown trout) and 1912 (rainbow trout) to 1950. During 1950-1985, the annual mean size of trout in anglers' catch and spawning migrations stabilized; overall mean weights of brown trout and rainbow trout were, respectively, 1.2 and 1.0 kg in the anglers' catch, and 1.4 and 1.5 kg in spawning migrations. Four stages were evident in the fishery: initial dominance of brown trout prior to 1920, rainbow trout dominance in anglers' catch and spawning migrations during 1920-1940, declining numbers of rainbow trout and mean weight in catch from 1940 to 1950, and equal representation of both species in angler catches with a predominance of brown trout in spawning migrations from 1950-1985. Various correlations between lake levels, the size of trout in angler catches and spawning migrations, and the species composition of catch and spawning migrations are explained in terms of inundation of new ground, location of feeding zones and bias due to angling method. Mean weight of fish in the catch was inversely correlated with minimum lake depth during the period 1945 to 1985. Characteristics of the recreational fishery were evaluated from license form census data from 1945-46 to 1957-58 and from postal questionnaire returns for the 1985-86 and 1986-87 seasons for full-season license holders. A significant decrease in catch-per-angler day since the 1945-57 period has been accompanied by an increase in the total harvest, an increase in days fished per angler, and an increase in the number of anglers fishing the lake. These changes have not been accompanied by significant changes in the mean catch weights or the length-frequencies in anglers' catches or in the spawning migrations of either trout species. Two management strategies, removal of spawning brown trout and stocking with juvenile rainbow trout, failed to significantly increase the proportion of rainbow trout in the catch or in the spawning migrations. Man-made environmental changes and lake-level fluctuations associated with management for hydroelectric power generation are considered the dominant influences on the dynamics of the trout populations in Great Lake.

DAVIES, P. E., R. D. SLOANE and J. ANDREW. 1988. Effects of hydrological change and the cessation of stocking on a stream populations of *Salmo trutta*. Australian Journal of Marine and Freshwater Research 39(3) : 337-354.

The North Esk-St Patricks river system, northern Tasmania, was electrofished at 27 sites in 1985, 30 years after the same sites has been electrofished in a previous study on the survival of released brown trout (*Salmo trutta*). All sites were dominated by brown trout. Before 1955, stocking of brown trout fry and yearlings had been heavy. Stocking ceased after 1956 and few releases were made to 1985. At all but 4 sites, the number and total biomass of brown trout were higher in 1985 than in 1955. The estimated total population of brown trout had increased by 63%, accompanied by a 55% increase in the number of fish of legal size (> 22 cm). Previously described "nursery streams" still maintained high densities of 0+ fish, despite considerable changes in the age composition at other sites. Little or no change had occurred in riparian habitat at 23 of 27 sites.

DEAN, J. 1959. Creel census and stocking evaluation of Spearfish Creek, South Dakota, 1958. Federal Aid Project F-1-R-8, Job No. 7-A. South Dakota Department of Game, Fish and Parks. Pierre, South Dakota. 20 p.

DEBOWSKI, P. and R. BARTEL. 1995. Homing of tagged sea trout (*Salmo trutta*) smolts released into Polish rivers. Archiwum Rybactwa Polkiego 3(1) : 107-122.

About 183,000 sea trout (*Salmo trutta*) smolts were tagged in 1961-1986 and released into the Vistula River system, the Pomeranian rivers (Poland), and the Gulf of Gdansk. The Vistula River stockings showed the highest percentage of recaptures in rivers, almost all fish were caught in this system. Many sea trout from the stocking of the Pomeranian rivers went astray and were recaptured either in Vistula River or in the Pomeranian rivers. It seems that local Pomeranian sea trout may be a mixture of populations stemming from the neighbouring rivers. This concerns in particular the cases when the share of smolts from stocking is very high.

DEBOWSKI, P. and R. BARTEL. 1996. Stocking of sea trout (*Salmo trutta trutta*) smolts in Poland. Part 2: Factors influencing recaptures and verification of estimates. Archiwum Rybactwa Polskiego 4(1) : 19-36.

Recaptures of tagged sea trout (*Salmo trutta trutta*) smolts released in Poland during 1961-1986 depended on the place of rearing and on at least two other variables. In case of releases into the Vistula River system the rate of recapture was related to the distance of the releasing place from the sea and to calendar years, exhibiting a decreasing trend. Releases to the Pomeranian rivers and directly to the sea were significantly affected by the mean length of tagged smolts and also to the calendar years. These relationships determined approximately 40% of variation effects (i.e. of weights of recaptured fish per 1,000 released smolts).

DEBOWSKI, P., K. GORYCZKO and W. WISNIEWOLSKI. 1992. Survival and growth of sea trout (*Salmo trutta*) released as hatched fish into the Upper Parseta River. Rocz. Nauk. Pol. Zwiazku. Wedkarskiego 5 : 125-136.

DEGAN, D. 1980. Experimental spring stocking of fingerling brown trout in put-and-grow streams. Job Completion Report. Fisheries Section, Iowa Conservation Commission. Des Moines, Iowa. 5 p.

DEGROOT, S. J. 1985. Introduction of non-indigenous fish species for release and culture in the Netherlands. Aquaculture 46(3) : 237-257.

A total of 27 non-indigenous fish species have been introduced into the waters of the Netherlands, mainly during the 19th and 20th centuries: 12 European, 11 North American, 3 Asian and 1 South American species. Most of the introductions were made deliberately, some accidentally. Nearly all of the introduced fish are true freshwater species (23), while the others are anadromous (4). The introductions were made with the aim of restocking declining populations of commercially important species, as well as introducing produce fish for consumption, ornament and game. The extensive and prolonged attempts to restock inland waters with various salmonids have never met with success. The introduction of non-indigenous salmonids (e.g. chinook, lake whitefish) was also a failure. Even at the beginning of this century the inland waters of The Netherlands had become unsuitable for salmonids because of environmental deterioration although that was not understood at the time. The release of rainbow trout into natural waters is unsuccessful as they will not reproduce. Apart from the carp, the most successful introduction since mediaeval times has been the pikeperch (1901) which at present is the second most important freshwater species for fisheries. Four North American species, probably accidentally released, are fully acclimatized in our waters, and are even locally common. These are the eastern mudminnow, the black and brown bullhead and the pumpkinseed.

In the early 1920s, juvenile sea trout (*Salmo trutta trutta*) were released for the first time in the rivers Meuse and Gelderse Ijssel, and in the Alkmaarder Lake. In the winter of 1936/1937, 400,000 fertilized sea trout eggs were obtained in Denmark for release as juvenile fish (2-3 cm) in the same rivers. Danish hatcheries still provide sea trout fry for export and release in several European countries.

De ROCHA, A. J. and D. H. MILLS. 1984. Utilization of fish pellets and wood fragments by brown trout (*Salmo trutta*) in Cobbinshaw Reservoir, West Lothian, Scotland. Fisheries Management 15(3) : 141-142.

This short communication reports the occurrence of previously unrecorded food items from the diet of brown trout (*S. trutta*) stocked in an upland reservoir, namely fish pellets and wood fragments. Fish pellets consumed by the fish had presumably penetrated through the mesh of rearing cages sited in the reservoir. Cobbinshaw Reservoir is a 127 hectare feeder reservoir situated 25 miles west of Edinburgh (Scotland). Since 1906, when trout were first introduced into the reservoir, various stocking programmes have been adopted. More recently, the reservoir has been stocked annually with 1+ and 2+ year-old trout. Younger fish are placed in rearing cages in the centre of the reservoir before their release in the autumn. Fish in these cages are fed with unpigmented high density pellets (Edward Baker-Omega). A number of trout caught by anglers during the 1982 fishing season (1 April-30 September) were examined and their stomach contents analysed. Most of the fish examined were 2+ and 3+ years old, with a predominance of the former. During the period of this study the trout were found to feed intensively and very few fish were found with empty stomachs. During April and May the trout diet consisted chiefly of caddis larvae. In June, their food was mainly perch fry, but fish pellets were also consumed. Fish pellets occurred in every month from June to September but were of greatest importance in September.

DEVERILL, J. I., C. E. ADAMS and C. W. BEAN. 1999. Prior residence, aggression and territory acquisition in hatchery-reared and wild brown trout. Journal of Fish Biology 55(4) : 868-875.

In an artificial stream environment, established wild brown trout initiated 44% of the mean aggressive acts while hatchery-reared trout initiated 34% and introduced wild trout initiated 22%. Established wild fish maintained home stations closer to a point source of feed than did both hatchery-reared and introduced wild conspecifics. Established wild fish were the only group to show a positive mean specific growth rate during the trials. Introduced wild fish showed a slightly negative mean specific growth rate, while introduced hatchery-reared fish exhibited a considerable negative mean specific growth rate. These results suggest that established wild brown trout in a semi-natural stream environment display a prior-resident effect over late introductions of hatchery-reared and wild conspecifics. Introduced hatchery-reared fish were more aggressive and exhibited a lower mean specific growth rate than simultaneously stocked wild fish, suggesting than excessive expenditure of energy for unnecessary aggression may contribute to the poor survival of hatchery-reared fish after they are stocked into streams.

DEVLIN, G. J. N and P. W. BETTOLI. 1998. Performance of stocked salmonids in the Caney Fork River, below Center Hill Dam, Tennessee. Presented at the 1998 Southern Division of the American Fisheries Society midyear meeting held in Lexington, Kentucky. (Abstract only)

Population characteristics of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) stocked into the Caney Fork River below Center Hill Dam in 1997 were investigated. Three cohorts of rainbow trout (N = 7,000) and one cohort of brown trout (N = 16,500) were microtagged and stocked during the spring and summer of 1997. The river was sampled monthly by electrofishing to assess the survival, growth, condition, and movement of trout. Electrofishing catch-per-unit-of-effort (CPUE) for rainbow trout stocked in March declined linearly ($r^2 = 0.92$) and CPUE reached zero within 167 days. The CPUE for rainbow trout stocked in June declined rapidly ($r^2 = 0.93$) and approached zero within 102 days. Brown trout stocked in May did not exhibit a decline ($r^2 = 0.07$) in CPUE. Early stocked rainbow trout grew faster (13 mm and 21 g/month) than later stocked rainbow trout (8 mm and 5 g/month). Brown trout grew 10 mm and 9 g/month. All tagged cohorts exhibited a decline in condition throughout the study. Brown trout stocked at the lower end of the tailwater exhibited continual upstream movement; rainbow trout displayed little appreciable movement. A mark-recapture experiment in April 1997 estimated that 2,826 brown trout and 4,818 rainbow trout overwintered.

DeWALD, L. and M. A. WILZBACH. 1992. Interactions between native brook trout and hatchery brown trout: Effects on habitat use, feeding and growth. Transactions of the American Fisheries Society 121(3) : 287-296.

Habitat use, feeding behavior, and growth of native brook trout (*Salvelinus fontinalis*) and hatchery brown trout (*Salmo trutta*) were compared in an experiment in which the two species were held alone and together in laboratory stream channels at 14° C. Microhabitat location and vertical distribution of brook trout within the stream channels shifted in the presence of brown trout, and the frequency with which brook trout initiated aggressive interactions declined. Prey capture rates were higher for brown trout than for brook trout in single- and mixed-species trials, and higher for both species when they occurred alone than when they were together. Brook trout and brown trout in single-species trials maintained weight, but did not grow. In the presence of brown trout, however, brook trout lost weight. Instantaneous growth rates of brown trout in mixed species trials were positive. In the presence of brown trout, 33% of the brook trout contracted the fungus *Saprolegnia* sp. and died; brown trout were never infected nor were brook trout in single-species trials. If these changes in behaviors and growth rates extend to natural settings in which brook trout and brown trout co-occur, they may contribute to an explanation for the observed decline of brook trout abundance in North America.

DEXTER, J. L., Jr. 1991. Angler catch and densities of stocked and wild brown trout in August Creek, Michigan. Fisheries Technical Report No. 91-9. Michigan Department of Natural Resources. Lansing, Michigan. 17 p.

In 1989, and again in 1990, 5,900 spring yearling brown trout (*Salmo trutta*) were stocked in August Creek, Kalamazoo County, Michigan. Fifty percent of the fish in 1989, and 25% in 1990, were tagged with Floy tags to permit an estimate of angler catch rates. Catch rates of stocked brown trout by anglers ranged from 3.3-13.2% in 1989 to 2.8-8.2% in 1990. Catch rates were adjusted to account for tags that were shed over the course of the fishing season. No adjustment was made for non-reporting of trout caught with tags. Floy tag loss in brown trout was up to 77.8% after 200 days. The average cost per brown trout caught in 1989 and 1990 ranged from $5.70 to $26.31. Fall population densities of brown trout in August Creek (162/acre, 38.3% legal size) did not compare very favorably with several other area streams. Relative densities of stocked versus wild trout decreased substantially through the season. Stocked trout comprised 97% of the estimated number of trout after stocking in April compared to 69% in late October. I believe recruitment of wild trout to legal size (8 inches) was low and may have been negatively impacted by stocking of hatchery trout or a lack of overwinter habitat and cover.

DIEPERINK, C. 1995. Depredation of commercial and recreational fisheries in a Danish fjord by cormorants (*Phalacrocorax carbo sinensis*). Fisheries Management and Ecology 2(3) : 197-207.

The conflict between the cormorant (*Phalacrocorax carbo sinensis*) and commercial and recreational fisheries was investigated in the foraging area of a cormorant colony of 5000 breeding pairs in Horsens Fjord, Denmark. Depredation of commercial pound nets was studied by stocking a large net pen with hatchery-reared rainbow trout (*Oncorhynchus mykiss*). When avian predation was precluded with a cover net, background mortality was around 15%/day. When the cover net was removed, mortality increased to 98%/day. Direct observation revealed that a flock of cormorants emptied the pound net in about 30 minutes, consuming 110 fish weighing a total of approximately 50 kg. The cormorants were able to catch trout weighing more than 1 kg (i.e. almost 50% of their own body weight). The impact of the cormorant colony on recreational fishing in the area was studied by stocking Carlin-tagged sea trout (*Salmo trutta*) smolts into the two rivers that drain into the fjord. The cormorant colony lies between the river outlets and the open sea. Tag recovery from a 3-year programme was only about 2%, compared with about 10% for smolts stocked in areas of low cormorant density.

DUMONT, P. and J. R. MONGEAU. 1990. An evaluation of the introductory trials of the brown trout (*Salmo trutta*) in the waters of the Montréal Lowlands, Québec. Bulletin Français de la Pêche et de la Pisciculture 319(4) : 153-166.

Introduced into North America in 1883, brown trout (*Salmo trutta*) was planted for the first time in Québec in 1890. However, it was only at the beginning of the 1950s that this species began to raise interest among Quebéc wildlife managers, biologists and fishermen in comparison to native charrs (*Salvelinus* spp.), on account of its greater tolerance for rather high temperatures and interspecific competition. In 1965, the discovery of this species in the lowlands of the Montréal area, considered of poor interest for salmonids, has been the starting-point of a sustained planting program in the St. Lawrence River and in the lower reaches of a certain number of its tributaries. In spite of the relatively high summer temperatures (maximum > 25° C) and the abundant and diversified fish fauna in these waters, the brown trout thrives successfully and grows rapidly. Its sport fishing yield is satisfactory as to fishing success, size of specimen caught and amount of fish planted returned.

DYMOND, J. R. 1955. The introduction of foreign fishes in Canada. Proceedings of the International Association of Theoretical and Applied Limnology 12 : 543-553.

ECKERT, T. H. 1982. Brown trout management in Lake Ontario, 1973-1982. New York State Department of Environmental Conservation. Albany, New York. 44 p.

This report provides a review of the New York Department of Environmental Conservation's efforts to develop and manage a brown trout fishery in Lake Ontario, and also serves as a reference document for the 1983 Lake Ontario brown trout management plan.

Stocking and sampling activities from 1973-1982 are summarized, and plans and recommendations for future work are included.

Overall brown trout performance is rated as excellent and evidence is presented that brown trout are now the most commonly captured salmonid in Lake Ontario. Specific topics covered that deal with brown trout performance include distribution, abundance and age frequency data, survival data, growth, parasitism, and contaminant data.

The Lake Ontario brown trout fishery is discussed including estimates of current use.

EIPPER, A. W. 1953. The effect of hatchery growth rate on the survival of brown trout planted in Fall Creek, New York. Ph. D. Dissertation, Cornell University. Ithaca, New York. 151 p.

EIPPER, A. W. 1963. Effect of hatchery rearing conditions on stream survival of brown trout. Transactions of the American Fisheries Society 92 : 132-139.

Groups of brown trout which had experienced normal and temperature retarded growth in the hatchery were stocked in a 5-mile section of Fall Creek, New York, to compare their natural mortality rates during the season directly following spring stocking. "Normal" trout were reared in Cortland, New York, hatchery water averaging 54° F and varying annually from 39-60° F; "retarded" trout were reared in a different water supply at Cortland which remained at approximately 47° F year-round. Observations on movement (from tag returns), rates of exploitation (from creel census), and total mortality (from electrical inventories in June and September) provided the data needed to compute natural mortality rate (*n*) of each experimental lot in the first and second parts of both the 1949 and 1950 seasons. Yearling and two-year-old retarded trout usually had higher natural mortality than did yearling normals in both parts of both seasons. The higher mortality rates among the retarded trout were particularly evident in the second parts of the seasons, when higher water temperatures prevailed. At time of stocking in 1949, yearling normal trout had harder body fat (lower iodine number) than the yearling retarded trout. In a 6-week test in Cascadilla Creek in the spring of 1951, yearling normals again had lower natural mortality than yearling retarded trout, although water temperatures never became critically high. These findings suggest that characteristics of the hatchery water supply can influence natural mortality rate of brown trout after stocking. High temperature acclimation may be one component of this influence, but apparently it is not the only component.

ELLIOT, W. P. 1975. Returns of stocked yearling brook, brown and rainbow trout from six two-story ponds, 1971-1974. File Report. New York State Department of Environmental Conservation. Albany, New York. 23 p.

EMERY, L. 1985. Review of fish species introduced into the Great Lakes, 1819-1974. Great Lakes Fishery Commission Technical Report No. 45. Ann Arbor, Michigan. 31 p.

In 1883, brown trout eggs were shipped to the United States and as a result fry were placed into the Pere Marquette River (tributary to Lake Michigan). At this time fry also escaped from a New York Hatchery into the Genessee River (a tributary to Lake Ontario). Ultimately, all states bordering the Great Lakes, along with Canada began stocking brown trout into the Great Lakes. Many self-sustaining populations erupted as a result of early stockings and in the 1960s and 1970s fisheries developed in many of the Great Lake tributaries. Stocking is requried however, to supplement natural populations.

ENGSTROM-HEG, R. 1990. Guidelines for stocking trout streams in New York State. New York State Department of Environmental Conservation. Albany, New York. 107 p.

Improving trout waters includes many different approaches such as stocking to rehabilitate a depleted population. Typically, if a stream is easily accessible to the public and has adequate trout habitat, but inadequate natural reproduction, trout are stocked for angling purposes. The purpose of Catch-Rate Oriented Trout Stocking (CROTS) is to stock trout in areas which are fished regularly, while in turn allowing for the survival and growth of those trout which are not captured.

This paper covers the considerations which need to be made when contemplating stocking various water bodies. Topics covered include procedures necessary for assessing the fishing intensity, estimating the carrying capacity of stocked trout, the use of past survey data and dealing with specific problem areas such as size of fish to stock and timing of stocking.

It has been found that when the mid-April stocking is replaced with the ratio of 1.73 fingerlings per recommended yearling the post-stocking biomass may be a little lower than with yearlings. To ensure good growth the same biomass equivalents of fingerlings and yearlings should be used. Yearlings hould be stocked that are at least nine inches in length (greater than the protection length limit) in order to contribute to a fishery in the first year of release. Smaller fish may occassionally be used in streams having high growth rates. Stream sections lacking year-round trout habitat should not be stocked, as shouldn't: stream sections less than a mile or narrower than ten feet, or sections which would receive less than 300 fish in total; streams with light fishing pressure; streams which support adequate smallmouth bass or walleye fisheries. The sections of a stream which are to be stocked should be spaced evenly throught the open (non-posted) portion of stocked section.

FAHY, E. 1983. Have hatcheries a role in sea trout management? Fishery Leaflet (Dublin) No. 122. 12 p.

FAJFER, S. J. and B. P. BELONGER. 1997. The introduction of Seeforellen brown trout into Green Bay and Lake Michigan and their performance characteristics. p. 430. *In* The 59th Midwest Fish and Wildlife Conference, December 7-10, 1997, Milwaukee, Wisconsin. (Abstract only)

Over a 3 year period 578,000 brown trout of three different strains were stocked as marked yearling fish in the waters of Green Bay and Lake Michigan. Seeforellens were compared to domestic Wild Rose and feral Wild Rose strain fish. Preliminary results show any of the three strains can provide good fishing as two-year old fish. Seeforellens did live longer and grow faster than the other two strains, including two new state record brown trout in 1996. Seeforellens also returned to rivers and spawned at later dates than the other two strains.

FERGUSON, M. S. 1983. Survival of brown trout produced in a streamside incubation box and stocked in Deer Creek. File Report. Ontario Ministry of Natural Resources. Simcoe, Ontario. 13 p.

In April, 1982, 6,677 brown trout (*Salmo trutta*) fry reared in a streamside incubation box were stocked into Deer Creek. Before stocking, this coldwater stream contained a remnant population of brown trout suffering from poor natural reproduction. This study estimated the survival of stocked fry from the time of stocking to the end of their first summer. Also, proportion of stocked trout in the 1982 year class was estimated at the subyearling (age 0+) and yearling (age 1+) stage.

A backpack electroshocker was used to collect fish at three stream stations affected by trout stocking and one station unaffected by trout stocking in late the summer of 1982 and 1983. Total numbers and density of trout were estimated using the population removal method.

Survival of stocked fry to the end of their first summer was estimated to be 14.4% of the number stocked. Stocking brown trout fry produced subyearling trout densities in 1982 (1431/ha) that were four times greater than that produced entirely by natural reproduction in 1983 (341/ha). A comparison of the number of yearling trout captured in 1983 (40) with that in 1982 (13) suggests that stocking fry has had a positive impact on the stream trout population 16 months after stocking.

FERGUSON, M. M., P. E. IHSSEN, and J. D. HYNES. 1991. Are cultured stocks of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) genetically similar to their source populations? Canadian Journal of Fisheries and Aquatic Sciences 48(1) : 118-123.

The Ontario Ministry of Natural Resources (OMNR) implemented a controlled breeding program in the early 1980s with the objective of culturing fish that are genetically representative of the source populations. We describe the OMNR broodstock management plan for brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) and test its effectiveness by comparing the allozyme variation of the source fish collected from the Ganaraska River, Ontario to several descendant hatchery lines. Ancestral and descendant rainbow trout do not show significantly different allele frequencies. However, significant differences were detected in brown trout. The absence of several rare alleles in hatchery fish can be explained by sampling error rather than inappropriate propagation methods. Hatchery stocks of either species do not show reduced enzyme heterozygosity compared to wild fish suggesting that the OMNR hatchery system has been successful in retaining allelic variation during broodstock founding and propagation.

FITCH, L. A. 1977. Trout stocking in streams: A review. Alberta Department of Recreation, Parks, and Wildlife, Fish and Wildlife Division. Lethbridge, Alberta. 24 p.

This paper serves as an examination of trout stocking studies and incorporates information uncovered by others into its recommendations.

The survival of stocked trout varies by species. In one experimental set it was found that brown trout had a survival rate between 16 and 100%, intermediate to the results of rainbow and brook trout. Further, overwinter survival was determined to be 27% for ten-month-old fish, while fingerlings had between an 18-25% chance of surviving winter conditions.

Stocking site can potentially play a major role in the survival of hatchery brown trout. It was found that for fish age 0 to age 1 a survival rate of 19.6% occurred in unsuitable habitat, while that in favourable habitat was 48%.

The yield of stocked trout is key in determining the contribution of stocked brown trout to the creel. In streams with large resident brown trout populations the survival to the creel of planted fall fingerlings was found to be 6%, whereas low residential numbers allowed a return to the creel of 15-21%.

FJELLHEIM, A., G. G. RADDUM and B. T. BARLAUP. 1995. Dispersal, growth and mortality of brown trout (*Salmo trutta*) stocked in a regulated west Norwegian River. Regulated Rivers: Research and Management 10(2-4) : 137-145.

As part of a fishery enhancement scheme, 70,000 fingerlings of anadromous brown trout (*Salmo trutta*) were stocked in the regulated River Teigdal, western Norway. To evaluate the stocking programme 10,000 of the hatchery-reared fish were marked and released at 10 different localities. The results showed that the hatchery-reared fish were inferior to wild brown trout. During the first weeks densities were high in the areas of stocking, varying between 27 and 680 individuals per m^2. Stocked fish colonizing adjacent areas were mostly found upstream. Very few fish were found to cross the river from the point of release. One week after stocking food consumption of the hatchery-reared fish was low compared with wild trout. Stocked trout had a lower growth rate (0.05 mm/day) than native fish (0.08 mm/day). However, fish stocked in deeper, slower flowing areas grew faster than those stocked in shallow riffle areas. The mortality of the stocked trout was 99% from July to April, being the highest during the winter. Wild fish survived better, having a mortality of 79% over the same period. The value of the stocking programme is questioned. As an alternative, methods of biotope adjustment are proposed to increase the carrying capacity of wild trout in the river.

FJELLHEIM, A., G. G. RADDUM and H. SÆGROV. 1993. Stocking experiments with wild brown trout (*Salmo trutta*) in two mountain reservoirs. p. 268-279. *In* I. G. Cowx [ed.]. Rehabilitation of Freshwater Fisheries. Fishing News Books, Blackwell Scientific Publications. Oxford, England.

FRANKENBERGER, L. 1969. Evaluation of brown trout fingerling stocking problems in the Lower Willow River and the economics thereof. Fisheries Management Report No. 24. Wisconsin Department of Natural Resources. Madison, Wisconsin. 16 p.

Fingerling stocking of brown trout in the Lower Willow River and Race was evaluated at two different stocking denties over a 6-year period.

While stocking at high densities, overwinter survival varied from 20-26.3%. Cost analysis on a per fish basis revealed that spring stocking of legal brown trout in numbers equal to the number of fall fingerling survivors would have been significantly cheaper and would have provided the angler with substantially larger fish.

Stocking fall fingerling brown trout at lower densities resulted in overwinter survival rates of 11.6 to 40.1%. Using the 3-year average, it was again determined that an equal number of larger spring planted legal brown trout could have been provided at less cost.

Under present stocking practices and policies, it is apparent that in this stream, the stocking of legal-size trout each spring will provide more and larger fish per dollar than will a fall fingerling program.

GARCIA-MARIN, J. L., P. E. JORDE, N. RYMAN, F. UTTER and C. PLA. 1991. Management implications of genetic differentiation between native and hatchery populations of brown trout (*Salmo trutta*) in Spain. Aquaculture 95 : 235-249.

Isozyme electrophoresis was used to assess the amount and distribution of genetic variation among natural populations and hatchery stocks of brown trout (*Salmo trutta*) in Spain. Genetic variation was found at 19 out of 50 protein coding loci.

The hatchery stocks were conspicuously different from the natural populations, and the two groups appeared to represent distinctly divergent evolutionary lineages of brown trout. The hatchery stocks were highly polymorphic but also markedly homogenous; only 3% of the total genetic variation was explained by stock differences, indicating a common origin for these stocks. In sharp contrast to the hatchery stocks, the natural populations were found to be highly divergent, and more than 60% of their total genetic variability was due to differences between populations.

There is evidence indicating impending or actual loss of natural populations by intrusions of fish of hatchery origin or ancestry. In the interest of optimal resource management, we recommend that the indigenous populations of Spain be fully identified and protected, and that the existing hatchery stocks be replaced with local natural populations.

GARCIA-MARIN, J. L., N. SANZ and N. PLA. 1998. Proportions of native and introduced brown trout in adjacent fished and unfished Spanish rivers. Conservation Biology 12(2) : 313-319.

Evidence of different degrees of genetic interactions of exogenous hatchery fish with native populations was electrophoretically obtained from collections of brown trout from four heavily fished areas and eight adjacent protected areas in northeastern Spain. Although some degree of hybridization or introgression was detected in each collection based on fixed differences between hatchery and native fish at the LDH-C* locus and less distinct differences were found at three other loci (sMDH-A2*, IDHP-2*, IDHP-3*), fished populations had significantly lower levels of hatchery genes than protected ones. The greater persistence of native fish in areas that were fished and stocked appeared to reflect a greater susceptibility of hatchery-reared fish to angling. Although it remains uncertain whether this difference is innate or a reflection of hatchery-rearing, stocking was ineffective in enhancing the recipient population in the exploited river. These data suggest that different strategies may be needed for protection of native populations in fished and protected areas and that much more intense measures may be required in the latter instance.

GARCIA-MARIN, J. L., N. SANZ and C. PLA. 1999. Erosion of the native genetic resources of brown trout in Spain. Ecology of Freshwater Fishes 8(3) : 151-158.

We analyzed the introduction of hatchery-reared trout in the Riutort Creek, a small stream in the eastern Spanish Pyrennees. We used gene correlation matrices between individuals to analyze the fish coancestry in the Riutort Creek samples and in the hatchery stock. Hatchery fish disturbed the single ancestry in the native population of the creek, and were clearly detected with principal coordinate analysis of the gene correlation matrix. The amount of introgression produced by successful introductions was estimated from the principal coordinate analysis projections of the matrix of F_{ST} values between the putative native Riutort Creek population, the hatchery stock and the introgressed population. In only two years the amount of introgression rose to 10%, indicating that 5% of the native ancestry is lost each year as a result of the stocking program. Based on these results, we review the present understandings on the genetic impact of hatchery fish on indigenous Spanish brown trout populations. The stocking of these populations involves a non-native broodstock widespread through the Spanish hatcheries, but successful stocking appears to be limited to wild populations subjected to occasional releases in protected or unfished areas. Surprisingly, extensive stocking in fished areas result in a more limited genetic impact on the recipient native population.

GARMAN, G. C. 1980. Impacts of stocked brown trout (*Salmo trutta*) on the native fish and fauna of Bottom Creek, Virginia. M. Sc. Thesis, Virginia Polytechnical Institute. Blacksburg, Virginia. 81 p.

GARMAN, G. C. and L. A. NIELSEN. 1982. Piscivority by stocked brown trout (*Salmo trutta*) and its impact on the nongame fish community of Bottom Creek, Virginia. Canadian Journal of Fisheries and Aquatic Sciences 39 : 862-869.

The magnitude of fish consumption by brown trout (*Salmo trutta*) was assessed by experimentally stocking large (>280 mm) and small (<280 mm) brown trout in separate sections of a Virginia stream. Large brown trout ate five species of fish consistently during the May-November, 1979 experimental period; by November every trout stomach examined contained fish remains. Small trout rarely ate fish. Effects of fish consumption were apparent in trout growth and in abundance of prey species. Large trout grew 9.4% in length and 21.3% in weight, whereas small trout grew 4.5% in length and 4.7% in weight. Abundance of the major prey species, torrent sucker (*Moxostoma rhothoecum*), decreased between April and October in the stream section containing large trout, but remained constant in a comparable reference section; estimates of total consumption of torrent suckers by brown trout accounted for a large portion of the decrease in abundance. Predation on torrent suckers was selective for smaller individuals. The field experiment indicates that stocking larger-sized brown trout may enhance growth and survival of brown trout, but that standing crops of non-game species are likely to decline.

GLENN, C. L., A. O. BUSH and R. C. ROUNDS. 1989. Survival and growth of rainbow trout and brown trout in farm dugouts and winterkill lakes. Progressive Fish Culturist 51(3) : 121-126.

Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were stocked sympatrically in four eutrophic winterkill lakes in 1987 and 1988 and allopatrically in 20 farm dugouts (elsewhere called stock tanks) in 1987. Fish survival and growth were monitored to ascertain the feasibility of using brown trout as an alternative species in prairie aquaculture. In dugouts, survival of both species was similar (about 30%); brown trout had faster daily growth, but both species reached similar and marketable size (about 300 g) by harvest. Brown trout survived better than sympatric rainbow trout in lakes (44 versus 30%), but rainbow trout grew significantly larger than brown trout in four of six cases. Our experiments suggest that brown trout may be a viable alternative to rainbow trout in aquacultural operations.

GØNZI, A. 1982. Stocking of trout (*Salmo trutta*) in impounded rivers. Institute of Freshwater Research Drottningholm 1. 24 p.

Since 1976, the Research Group FAK (fishery management in river reservoirs) is managing experiments with stockings of brown trout (*Salmo trutta*) in river reservoirs in northern Sweden. In this paper the most important factors relating to the evaluation of the experiments are discussed both before (culture environment, tagging, transport) and after (biotope, exploitation, predation, food) stocking.

GØNZI, A. P. 1986. Stocking of brown trout (*Salmo trutta*) in river reservoirs. Institute of Freshwater Research Drottningholm 4. 81 p.

The results are presented of trout (*Salmo trutta*) stocking experiments in north and central Sweden reservoirs. Findings indicate significant differences in the stationary behaviour of upstream migrants and stationary stream dwellers and in their recapture rates. Recommendations are made for fishery management in river reservoirs, taking into account the characteristics of the trout and environmental characteristics of the reservoirs.

GOODMAN, B. 1991. Keeping anglers happy has a price. BioScience 41(5) : 294-299.

Brown trout fishing is enjoyed by anglers because of their aggressiveness and the level of difficulty required to catch them. Unfortunately, since its importation from Europe the brown trout has also had negative effects on other North American species. The brown trout has displaced the brook trout in many areas because of its superior ability to tolerate warm waters created by agricultural expansion and other streamside development.

GOUDREAU, C. J. 1998. Creating a fishery in the Bridgewater Tailrace, North Carolina. Presented at the 1998 Southern Division of the American Fisheries Society midyear meeting, Lexington, Kentucky. (Abstract only)

Studies in 1993 documented the existence of 46 fish species in the 29 km section of Catawba River between Lake James and Lake Rhodhiss, but game species were rare. Water chemistry parameters were considered to be normal. Water temperature ranged from 8-22° C, and low (<5mg/L) dissolved oxygen concentrations were restricted to a 3 km river segment from August to September. The lack of game fish was felt to be limited by reproductive success, possibly due to significant sediment input from a major tributary. In an attempt to establish fishable game fish populations, annual stockings of 30,000 fingerling smallmouth bass (1994-1997) and brown trout (1996-1997) were made. Boat electrofishing conducted in September 1996 and 1997 was limited, preventing the calculation of fish density or survival. Age and growth information determined from scales in 1996 were suspect, especially for brown trout which showed 1-2 false annuli. Calculations from otoliths in 1997 indicated growth of smallmouth bass was slow (206 mm at age 3) but very fast for brown trout (246 mm at age 1). W_r was high for smallmouth bass under stock size (mean 102), but declined for quality fish (mean 92). Mean W_r was 82 for brown trout under stock size, increasing to 95 for preferred fish. Stocking and fish and habitat sampling will continue for several more years to determine which species is best suited for local conditions.

GRANDE, M. and S. ANDERSEN. 1990. Effect of two temperature regimes from a deep and a surface water release on early development of salmonids. Regulated Rivers: Research and Management 5(4) : 355-360.

In order to test the effect of regulated water temperature on the development of eggs and alevins of three salmonid species, deep and surface water from an oligotrophic lake was pumped into a hatchery. Atlantic salmon (*Salmo salar*) clearly needed the highest number of degree-days to reach the different developmental stages while brown trout (*Salmo trutta*) needed just a little more than brook trout (*Salvelinus fontinalis*). Eggs and alevins developed in the surface water, which was colder in winter, needed a lower number of degree-days to reach the hatch and swim-up stages. In spite of this there was a considerable difference in time for hatching and start of feeding of fish in the two temperature regimes. This might have consequences for the reproductive success and competition between species in regulated rivers.

GREENBERG, L. A. 1992_a. Management briefs: Field survival of brown trout eggs in a perforated incubation container. North American Journal of Fisheries Management 12(4) : 833-835.

A different type of container was used to study overwinter survival of eggs of brown trout (*Salmo trutta*) in the field. Holes 10 mm or 14 mm in diameter were drilled in 1 cm thick plastic plates, and a single egg was placed in each hole. Each plate was wrapped in nylon netting and placed horizontally in an artificial redd at a burial depth of 7 or 15 cm. Overwinter survival of eggs was independent of burial depth and hole size, but more plates were washed out from the 7 cm than from the 15 cm depth. Mean survival prior to hatching was greater than 72%. These plates offer a promising way to study survival in natural streams.

GREENBERG, L. A. 1992$_b$. The effect of discharge and predation on habitat use by wild and hatchery brown trout (*Salmo trutta*). Regulated Rivers: Research and Management 7 : 205-212.

The effects of trout stock, discharge and predation risk on habitat use by brown trout (*Salmo trutta*) were studied in four artificial streams. Trout stock had no effect on habitat use as both wild and hatchery fish used similar habitats. The presence of pike (*Esox lucius*) caused trout to decrease their use of pools, the habitat in which pike occurred, and increased their use of other habitats. Decreasing discharge reduced available area of the stream and resulted in fewer fish in the shallow margins. Both decreased flow and increased predation risk caused more overlap in habitat use, and thus increased the potential for intraspecific competition, predation and the use of poorer habitats. The results illustrate the danger of applying habitat use relationships obtained from one stream to all other streams where habitat availability and biotic interactions may differ.

GUYOMARD, R., F. BERGOT and E. VIGNEUX. 1997. Consequences of fish introduction in the absence of reproductive isolation: Interest and limits of the experimental approach. Bulletin Français de la Pêche et de la Pisciculture 344-345 : 301-308.

Stocking generally results in artificial secondary contact and introgression between differentiated conspecific populations. The consequence of such introgressions on the genetic and phenotypic variation in wild stocks is an important concern of population genetics and fisheries management. Introgression can be studied directly on natural populations, but the comparison of the fitness of artificial crosses under experimental conditions offers an interesting alternative approach. In this paper, we report data on growth performance and reproductive success of first and second generation crosses between a domesticated stock and a wild Mediterranean population of brown trout (Nei's standard genetic distance between the two taxa = 0.10). Our results did not reveal any genomic incompatibility between the two taxa. They support the idea that selective effects are weak or non-existent in introgressed Mediterranean populations. In such conditions, low and temporary gene flow between distinct geographic entities could be beneficial to natural populations, and might be artificially established provided that it is compatible with the conservation of the genetic resources of the species. These recommendations hold for other species under similar circumstances.

GUYOMARD, R. and F. KRIEG. 1986. Evidence of gene flow between wild brown trout and restocking strain in two Corsican drainages. Bulletin Français de la Pêche et de la Pisciculture 303(4) : 134-140.

An electrophoretic analysis of brown trout (*Salmo trutta*) samples from different Corsican drainages and of the domesticated strain usually introduced in some of these drainages enabled the authors to define hatchery specific variants. These variants were not found in rivers which never received any planting. By contrast, they appear simultaneously in rivers where hatchery strains were continuously stocked, clearly indicating that genetic "contaminations" by restocking occurred in these drainages. Furthermore, the genotype analysis of the native samples showed that there is no complete reproductive isolation in the wild between the Corsican populations and the introduced strain.

HALE, J. G. 1950. An evaluation of the fall planting program for 18 month old brown trout in Fillmore County, Minnesota, including data of the 1948 and 1949 investigations. Fisheries Investigations Report No. 102. Minnesota Department of Natural Resources. St. Paul, Minnesota. 41 p.

A study of the growth, survival and catch rate of 18-month-old fall-planted brown trout was undertaken during 1948 and 1949 on Watson and South Branch creeks, Fillmore County, Minnesota. A survey of stream physical conditions was made at the same time.

Both streams are in the limestone region of southeastern Minnesota, arise as springs from caves with water temperatures of 48° F during the summers and flow through deeply cut valleys to join the Root River. Watson Creek is 2 miles long, has a gradient of 0.57%, an average depth of 1.29 feet in May and 0.83 in August, a rate flow of about 4 c.f.s and a bottom composed mainly of rubble, silt and boulders.

South Branch Creek is about 1.5 miles long, has a gradient of 0.62%, average depth of 1.42 feet in May and 1.00 feet in August, a rate flow of about 8 c.f.s., although higher rates were present in the spring and lower rates in the fall, and has a bottom of rubble, silt and ledge rock.

Both streams have periodic floods (although few occurred in 1948 and 1949), and water temperatures sometimes range up to the highest degree tolerated by trout (83° F on Watson and 65° F on South Branch Creek). Amount of shade is much greater over South Branch Creek.

Totals of 1,625 and 1,800 pelvic-clipped 18-month-old brown trout were planted in Watson and South Branch, respectively, in September 1947 and 1948. These fish averaged 7.2 inches total length in 1948 at planting time. There was no evidence of excessive mortality due to clipping or planting.

A voluntary creel census during 1948 failed to give necessary data. A complete creel census by fisheries personnel on the two streams during 1949 gave the following information: On Watson Creek, 363 anglers caught 481 trout (27.5% of the plant – survivors of the 1947 plant included). On South Branch Creek, 519 anglers caught 684 trout (34.4% of the plants – survivors of the 1947 plant included). Unmarked trout from nearby plantings were more common in South Branch Creek.

These returns are not far below those of spring-planted yearlings, but the catch per hour falls off more rapidly in these two streams. Fall-planted fish are caught early at a faster rate than spring-planted trout.

Use of the electroshocker showed that 60% of all planted trout had disappeared from the streams during the winter and spring before the angling season began. All accounts indicate that by September 1949, only 3.3% of the original plant remained in Watson Creek and 1.5% in South Branch Creek.

The marked trout grew from a total length of 7.2 inches at planting to 8.5 inches at opening day, 8.7inches in July and 9.2 inches by September last. No trout movement could be definitely established in Watson Creek except for movement out of the stream on warm days. South Branch Creek trout remained in place, but unmarked trout moved into the stream in mid-summer.

When compared with trout investigations in other states, and earlier work in Minnesota, the 18-month-old trout planting program compares favorably with spring planting programs as far as opening day catches go, but unfavorably in terms of later fishing. Cost of the program is higher and most of the trout taken by anglers are of hatchery origin.

HALE, J. G. 1952$_a$. The use of hatchery-reared brown trout in the management of southeastern Minnesota streams. M. Sc. Thesis, University of Minnesota. St. Paul, Minnesota.

HALE, J. G. 1952$_b$. Results from plantings of marked yearling brown trout (*Salmo trutta*) in the Sucker River and the west branch of the Split River and marked yearling brook trout (*Salvelinus fontinalis*) in Sucker River, Minnesota, 1951. Investigational Report 118. Fisheries Research Unit, Minnesota Department of Natural Resources. St. Paul, Minnesota. 11 p.

An equal number of fin-clipped adult brown trout (1,000 fish) and adult brook trout (1,000 fish) were released in the Sucker River in the spring of 1951. On the same date, 800 fin-clipped yearling brown trout were stocked in the West Branch of the Split Rock River. The contribution to the catch during the subsequent fishing season was determined by creel census and anglers' postal card reports. Marked brown trout returned to the creel from these streams made up from 2.5 to 4.0% of the entire trout catch. Marked brook trout, on the other hand, composed 16% of his entire trout catch from the Sucker River. The catch of marked brook trout represents a survival to the creel of 43% of the marked brook trout stocked. The brown trout survival to the creel was 10% in these streams.

Bud Creek, a tributary to the West Branch of the Split Rock, was also censused in 1951. This stream was stocked with unmarked fingerling brook trout.

Length-weight data on the two species of marked trout caught from the Sucker River indicated that marked brook trout were larger on the average than "resident" brook trout, but marked brown trout, on the other hand, were smaller on the average than "resident" brown trout. The majority of marked trout returned to the creel were caught within three-quarters of a mile of the site of planting.

It was concluded that from a planting of an equal number of both trout species that adult brook trout yield a much larger return (43%) to creel than adult brown trout (10%). In the Sucker River, brook trout stocking is necessary to maintain a population of catchable-sized fish.

The brown trout population of catchable-sized fish in this stream maintains itself without artificial stocking. Therefore, the brown trout stocking quota should be converted into a comparable number of brook trout. Since approximately 50% of the marked brook trout were caught in May and no marked trout were caught after July, it is advisable to stock 50% of the quota in May, 25% in June, and 25% in July.

HALE, J. G. 1954. Investigations on trout catch and populations in the West Branch of the Split Rock River, Lake County, Minnesota, 1951-1953. Bureau of Fisheries Investigational Report No. 148. Division of Game and Fish, Minnesota Department of Conservation. St. Paul, Minnesota. 14 p.

Creel census on the Split Rock River, a small forest brook trout stream in Lake County, Minnesota, showed an annual harvest of trout (mostly brook trout) during the years 1951, 1952, and 1953 of 27.4, 49.2 and 34.1 pounds per acre and 161, 386 and 162 trout per acre. These figures are based on the 12.9 acres (or 5.9 miles) in which 99% of the anglers fished.

In each of these years about 800 catchable trout (7-9 inches long) were planted; brown trout in 1951 and brook trout in 1952 and 1953. This was a stocking rate of about 62 trout or about 7.2 pounds per acre of stream censused. All planted trout were marked by fin-clipping.

Fishing pressure on the stream was 92.0 hours per acre in 1951, 228.8 hours in 1952, and 150.5 hours in 1953 and take of trout-per-man-hour in these years 1.74, 1.70 and 1.07.

Of the total number of fish caught, 1.8% were of planted brown trout in 1951, 12.6% of planted brook trout in 1952 and 10.8% of planted brook trout in 1953. Of the planted trout, 2.6% of the brown trout planted in 1951 were taken in that year; 79% of the brook trout planted in 1952 were taken; and 27% of the brook trout planted in 1953 were taken. Trout were planted in 1951 as a single stocking in May, but in 1952 and 1953 the brook trout were planted in three lots: one-half in April, one-fourth in June, and one-fourth in July.

Six stations, with a total area of 1.3 acres, were shocked with a stream shocker each September. Populations of trout found per acre were: 1951, 74 fish and 10.6 pounds; 1952, 208 fish and 20.3 pounds; and 1953, 233 fish and 24.6 pounds. The weight per acre of the residual fall trout population in each year was considerably less than the average harvest-per-acre by anglers. Age-class distribution of the trout taken by shocker shows that an adequate breeding population of trout is left in the stream.

HALE, J. G. and L. L. SMITH. 1955. Results of planting catchable size brown trout (*Salmo trutta*) in a stream with poor natural reproduction. Progressive Fish Culturist 17(1) : 14-19.

In certain streams with low/no natural reproduction the fishery can be supported using catchable-sized plantings. Watson Creek permitted little natural reproduction and appeared to be marginal trout water. Plantings of brown trout were executed in order to determine their effect on the fishery. Fall plantings of brown trout were considerably more expensive than those during or prior to the fishing season. The cost of maintaining trout fishing in this stream appears to be justified only if additional nearby waters are stocked to support the heavy spring fishing load.

HALE, R. S. and J. H. GRAY. 1998. Retention and detection of coded wire tags and elastomer tags in trout. Presented at the 1998 Southern Division of the American Fisheries Society midyear meeting, Lexington, Kentucky.

Tag retention (>95%) and easy tag detection were possible with blank coded wire tags and elastomer tags implanted in a variety of body locations of adult trout (*Salmo* and *Oncorhynchus* spp.). These tags were used in a generic way to differentiate 32 groups of brown trout (*Salmo trutta*,142-254 mm TL) and rainbow trout (*Oncorhynchus mykiss*, 80-314 mm TL) that were stocked at different times and locations in the Cumberland River, Kentucky. Retention rates (19-30 days) ranged from 92 to 100% for coded wire tags implanted in the snout, left cheek, and muscle near the left pectoral, pelvic, dorsal, adipose and caudal fins. Retention rates (24-30 days) ranged from 94-99% for elastomer tags placed in the left and right adipose eyelids and the caudal fin rays. Loss of coded wire tags by trout did not increase with the number of days tagged fish were held in raceways, which suggested that most tag loss was complete prior to stocking. By contrast, loss of elastomer tags increased with holding time and may have continued after stocking; therefore we recommend further investigation of elastomer retention. Two inexperienced creel clerks successfully detected the body locations of coded wire tags 91 and 98% of the time following only 1 hour of training. Detection of the presence or absence of coded wire tags was easy and precise. However, accurate determination of tag location could become a source of error if adjacent tags are too close due to the selection of tag locations or fish size. Visual detection of elastomer tags was enhanced by a black light but detection was obvious and required minimal training.

HAMBLY, L. S. 1968. Quabbin Reservoir investigation: Planting success of marked brown and rainbow trout. Federal Aid Project F-6-R-14, Job No. 3. Massachusetts Division of Fisheries and Game. Boston, Massachusetts. 5 p.

HANSEN, M. J. , P. T. SCHULTZ and B. A. LASEE. 1991. Wisconsin's Lake Michigan salmonid sport fishery 1969-85. Fisheries Management Report No. 145. Wisconsin Department of Natural Resources. Madison, Wisconsin. 71 p.

Wisconsin's Lake Michigan salmonid sport fishery began during 1963-69 with the stocking of rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*). The fishery grew rapidly during 1969-85 as angler effort increased ten-fold, catch rate doubled, and harvest increased twenty-fold. Stocking and catch were increasingly dominated by chinook salmon – with coho salmon and lake trout of secondary importance and brown, rainbow and brook trout of lesser importance. Trolling dominated the fishery – particularly by launched-boat anglers and, more recently, by moored boat anglers. Charter trolling grew the most continuously and had the highest catch rates. Chinook and coho salmon and lake trout dominated trolling catch. Pier, shore, and stream anglers fished less overall, but had catch rates similar to those of launched boat anglers. The catch by pier and shore anglers was spread among chinook and coho salmon, and lake, brown and rainbow trout. The stream-angling catch was dominated by chinook salmon. The percentage of stocked fish subsequently caught (catch ratio) was highest for fingerling chinook salmon (12.9%). Yearling brook and brown trout, coho salmon, and lake and rainbow trout had intermediate catch ratios (5.1-9.8%). Fingerling brook, brown, and lake trout had lower catch ratios (2.5-3.6%). The catch ratio for rainbow trout dropped from 9.8% to 5.1% following conversion to a different strain (the Shasta strain). Fingerling rainbow trout produced the lowest returns (<0.5%). Stocking recommendations were based on catch ratios, and catch objectives were based on 1982-85 average catches.

HANSEN, M. M., R. A. HYNES, V. LOESCHCKE and G. RASMUSSEN. 1995. Assessment of the stocked or wild origin of anadromous brown trout (*Salmo trutta*) in a Danish river system, using mitochondria DNA RFLP analysis. Molecular Ecology 4(2) : 189-198.

Declines in the number of anadromous brown trout in the Kara River in Denmark, due to environmental degradation, led to the stocking of large numbers of hatchery trout during the 1980s. This practice was gradually replaced by stocking with the offspring of electrofished local trout. The genetic contribution of the hatchery fish to the current population of anadromous trout in the river was estimated by restriction fragment length polymorphism analysis of mitochondrial DNA, using seven restriction endonucleases. Fish from the hatchery strain as well as from five locations in the river system, and from a further unstocked river were screened. Eight haplotypes were observed. The distribution and frequencies of the observed haplotypes revealed little genetic differentiation among stocked populations. The hatchery strain differed significantly from the stocked populations. One haplotype which was found at a high frequency in the hatchery strain was almost absent from the stocked populations. This suggests that the genetic contribution of the hatchery trout to the current population is much less than would be expected from the number of stocked fish. The possible reasons for the failure of the hatchery trout to contribute to the gene pool, and also the implications for conservation biology, are discussed.

HANSEN, M. M., E. D. RUZZANTE, E. E. NIELSEN and D. K. MENSBERG. 2000. Microsatellite and mitochondrial DNA polymorphism reveals life history dependent interbreeding between hatchery and wild brown trout (*Salmo trutta*). Molecular Ecology 9(5) : 583-594.

The effects of stocking hatchery trout into wild populations were studied in a Danish river, using microsatellite and mitochondrial DNA (mtDNA) markers. Baseline samples were taken from hatchery trout and wild trout assumed to be unaffected by previous stocking. Also, samples were taken from resident and sea trout from a stocked section of the river. Genetic differentiation between the hatchery strain and the local wild population was modest (microsatellite $F_{ST} = 0.06$). Using assignment tests, more than 90% of individuals from the baseline samples were classified correctly. Assignment tests involving samples from the stocked river section suggested that the contribution by hatchery trout was low among sea trout (< 7%), but high (46%) among resident trout. Hybrid index analysis and a high percentage of mtDNA haplotypes specific to indigenous trout observed among resident trout that were assigned to the hatchery strain suggested that interbreeding took place between hatchery and wild trout. The latter result also indicated that male hatchery trout contributed more to interbreeding than females. We suggest that stronger selection acts against stocked hatchery trout that become anadromous compared to hatchery trout that become resident. As most resident trout are males this could also explain why gene flow from hatchery to wild trout appeared to be male biased. The results show that even despite modest differentiation at neutral loci domesticated trout may still perform worse than local populations and it is important to be aware of differential survival and reproductive success both between life-history types and between sexes.

HANSEN, M. M. and V. LOESCHCKE. 1994. Effects of releasing hatchery-reared brown trout to wild trout populations. p. 273-289. *In* V. Loeschcke, J. Tomiuk and S. K. Jain [eds.]. Conservation Genetics. Birkhauser Verlag. Basel, Switzerland.

HANSEN, T. 1985. Artificial hatching substrate: Effect on yolk absorption, mortality and growth during first feeding of sea trout (*Salmo trutta*). Aquaculture 46(4) : 275-285.

Groups of sea trout (*Salmo trutta*) eggs were hatched in a California hatching system with and without astro-turf artificial substrate, and were later transferred to separate feeding units. Alevins reared in astro-turf absorbed their yolk faster and more efficiently than alevins reared on a flat screen, an effect which is probably caused by high activity stress in the flat-screened system. Probably due to higher yolk reserves, the fry hatched without astro-turf grew faster than the fry reared with astro-turf during the first periods of feeding. Later this was reversed, giving the astro-turf reared alevins the highest growth rate. The flat-screen-reared alevins/fry suffered higher mortalities during the experiment and the mortalities were clearly size dependent. These results have consequences both for intensive culture and stocking programmes since the traditional hatching systems both reduce growth and chance of survival of the fry.

HARSHBARGER, T. J. and P. E. PORTER. 1979. Survival of brown trout eggs: Two planting techniques compared. Progressive Fish Culturist 41 : 206-209.

Vibert boxes are commonly used in planting lake trout eggs in streams for incubation. We compared survival of eggs, embryos, and swim-up fry of brown trout (*Salmo trutta*) in direct intragravel plants and in Vibert boxes. We found that egg mortality increased disproportionately in Vibert boxes after 4 weeks until time of hatching. Direct intragravel plants yielded the highest survival to the swim-up stage.

HARSHBARGER, T. J. and P. E. PORTER. 1982. Embryo survival and fry emergence from two methods of planting brown trout eggs. North American Journal of Fisheries Management 2(1) : 84-89.

Survival of larval trout through the swim-up state was determined for eyed eggs of brown trout (*Salmo trutta*) planted both in the streambed and in Whitlock Vibert boxes. Tests were made in first, second, and third order streams and intragravel environmental factors were evaluated. Direct plants produced two times more sac fry than box plants and 3.5 times more swim-up fry. Sediment deposition was approximately 100% greater in first and second order streams than in third order streams, and sediments accumulated disproportionately in box plants. This seemed to account for survival differences between planting techniques and among stream orders.

HART, M. L. 1990. Assessment of a brown trout introduction to Lyn Creek. File Report. Ontario Ministry of Natural Resources. Brockville, Ontario. 31 p.

Lyn Creek is a small (24.1 km) stream in Leeds County. In response to local interest in a salmonid stream fishery, Lyn Creek was selected for the introduction of brown trout. Brown trout were first stocked on September 27, 1988 with 5,000 fingerlings and 155 brood stock. On May 31, 1989, 8,000 fingerling brown trout were planted.

The fish community of Lyn Creek was sampled, by electrofishing, on August 3 and 6, 1989. Twenty different fish species, including yellow perch, brown bullhead, fallfish, largemouth bass, smallmouth bass and pumpkinseed, were recorded. As the survey results indicate, Lyn Creek is dominated by a warmwater fish community. A total of 19 brown trout were captured. Trout were captured at two of the five sites sampled. Brown trout ranged from 9.5-18.5 cm in length.

HARTZLER, J. R. 1977. Analysis of angler effort and the catch of one-and two-year old hatchery trout on Spring Creek (Center County), Pennsylvania. Pennsylvania Cooperative Fishery Research Unit. M. Sc. Thesis, Pennsylvania State University. University Park, Pennsylvania. 70 p.

HARTZLER, J. R. 1988. Catchable trout fisheries: The need for assessment. Fisheries 13(2) : 2-8.

State fisheries agencies were questioned regarding their catchable-size (>178 mm) salmonid stocking programs, specifically: (1) Number, species and propagation cost of catchables stocked; (2) total length of stream and area of impoundments stocked; (3) methods used to estimate angler effort and harvest of catchables; and (4) extent to which these techniques have been employed in the past ten years. In 1983, 43 states stocked in excess of 50 million catchable-size trout at a production cost of nearly 37 million dollars. Rainbow trout (*Salmo gairdneri*) was the most popular species, predominating in 28 states and accounting for more than 77% of all catchable salmonids stocked. Brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were the next most frequently stocked salmonids (11.0% and 10.1% of total, respectively). More than 54,000 km of streams and 550,000 ha of ponds, lakes, and reservoirs were planted with catchables in 1983. Most methods utilized by management agencies to assess use and harvest required field personnel (complete creel census, partial creel survey with or without angler counts, spot checks); others were voluntary (fish tags, questionnaires, individual diaries). Although few states have conducted extensive surveys recently, most believe greater than 50% of stocked catchables are harvested. Possible reasons for the current de-emphasis of field surveys include: (1) budget and manpower limitations; (2) dependence on historical survey results; (3) increasing attention to wild trout fisheries; (4) lack of specific management objectives; and (5) labor intensive nature of creel survey work. Recognition of the value of creel and angler use surveys for evaluating and improving catchable salmonid programs is stressed.

HAUNSCHMID, R. and D. KOZAK. 1997. Post-stocking performance of catchable brown trout introduced to different types of streams in Upper Austria. Zeitschrift fur Fischkunde 4(1-2) : 49-71.

Catchable brown trout (*Salmo trutta*) (mean length was 25.1 cm) were stocked in the spring of 1995 at four streams of different types in Upper Austria. Two non-stocked streams were chosen to ascertain influences on the seasonal development of resident brown trout population. The stocking of brown trout had a significantly higher condition in the hatchery station compared to the resident fish in spring. Stocked fish showed heavy infection with *Gyrodactylus truttae*. The mean intensity was up to 50 times higher than that of the resident fish, whereas the mean intensity of *Trichodina* species was the same. When the stocked fish stayed in the stream for more than 40 days, the autumn biomass of resident fish was reduced, while the biomass increased at the non-stocked sampling areas from spring to autumn. Both the fish between 10 and 20 cm as well as fish >20 cm were considered. A correlation between stream width or maximum length of resident fish and the number of surviving stocking fish was estimated. Increase of length in stocked fish could not be found; they lost up to 10% of their initial weight. The significant difference in condition between stocking and resident fish could not be maintained until summer except at the sampling site having the largest width. The condition of stocking fish decreased gradually from spring to autumn. The mean parasite intensity of stocked fish with *Gyrodactylus truttae* diminished to half the amount from spring to autumn, but was ten times higher than that of resident fish, however, stocking fish showed a strong increase in the mean intensity of *Trichodina* from spring to autumn, which was then seven times higher than that of the resident fish. The stream without resident fish >25 cm showed the highest decrease of the stocking fish (2.5% per day). It can be concluded that stocking fish of that size were not able to adapt adequately and failed to increase the biomass and should not be used for stocking purposes also for ecological reasons.

HAUSER, L., A. R. BEAUMONT, G. T. H. MARSHALL and R. J. WYATT. 1991. Effects of sea trout stocking on the population genetics of landlocked brown trout (*Salmo trutta*) in the Conwy River system, North Wales, U. K. Journal of Fish Biology 39 (Supplement A) : 109-116.

The effect of the introduction of fry of anadromous sea trout (*Salmo trutta*) on the genetic integrity of landlocked brown trout populations was evaluated. Samples were taken from six brown trout populations from streams above impassable waterfalls in the Conwy River system (North Wales, U. K.) in 1989 and 1990. Three of these streams had no known stocking history and three had been stocked with sea trout fry from the lower Conwy system over the last few years. Representatives of these sea trout were collected from two streams in the lower Conwy system and from a hatchery. Allele frequencies at 13 loci, six of which were polymorphic, were determined by starch gel electrophoresis.

The stocked populations were intermediate in their allele frequencies between unstocked brown trout and sea trout samples. A principal component analysis suggested significant numbers of hybrids in all of the stocked streams. This shows that some of the introduced sea trout did not migrate down the falls to the sea, but stayed in fresh water and hybridized with the local population. The significance of this finding for conservation and genetic resource of brown trout stocks is discussed.

HEACOX, C. 1937. Introduction of the brown trout. Progressive Fish Culturist No. 30 : 39-40.

In the early part of 1883, Von Behr, a German fish culturist and the president of the Deutsche Erie Verein, sent the first shipment of brown trout eggs to the United States, more specifically, the Fish Hatchery at Northville, Michigan. Following the incubation of the eggs, the fry were planted in the Pere Marquette River and other streams in northern Michigan.

In the latter part of 1883, Von Behr sent further batches of brown trout eggs to Northville and the New York State hatchery at Caledonia, and the adult fish which resulted from these eggs became known as the German brown trout or the Von Behr brown trout.

In 1885, England sent eggs of the Loch Leven trout, a closely related species, to the Cold Spring Harbor Hatchery on Long Island, but they were then repacked and sent to Iowa, Minnesota and a private angling club in Herkimer County. This same year, Von Behr sent eggs of *Salmo fario*, also known as *Salmo trutta*, to the Corry, Pennsylvania hatchery.

Artificial stocking in our lakes seems to have been uniformly more successful than in our streams where brook, rainbow and brown trout are concerned. Summer stream temperatures between 60 and 70° F will be favorable for brown trout, if the oxygen level is approximately 3 cm^3/L and there is little pollution.

The Southern New York Fish and Game Association have conducted experiments with brown trout in the waters of the Kensico Reservoir, near White Plains. Since stocking began several years ago, good-sized browns have frequently been the reward of the skilled angler, but last year topped the most enthusiastic member's wildest hopes as nearly 100 brown trout over 5 pounds in weight were taken from the Kensico waters.

HEGGENES, J. 1988. Substrate preferences of brown trout fry (*Salmo trutta*) in artificial stream channels. Canadian Journal of Fisheries and Aquatic Sciences 45(10) : 1801-1806.

Brown trout fry (*Salmo trutta*) of two sizes (43 and 32 mm mean total length) preferred the coarsest gravel when allowed to choose between three sizes (8-16, 20-30 and 50-70 mm) at two temperatures (12.9-18.1 and 6.0-6.9° C) in artificial stream channels. Fry hid more in the substrate in daytime than at night and in daytime also hid more at low temperatures than at high temperatures. Increasing the average water velocity from 4 to 14 cm/s displaced the 43 mm fry slightly downstream at night. The 32 mm fry showed a weaker preference for the coarse substrate and, in general, had less pronounced diurnal substrate preferences.

HEIDINGER, R. C. 1993. Stocking for sport fisheries enhancement. p. 309-333. *In* C. C. Kohler and W. A. Hubert [eds.]. Inland Fisheries Management in North America. American Fisheries Society. Bethesda, Maryland.

Government-run and private hatcheries are currently raising sportfish for planting purposes. Because goals of stocking programs tend to be vague it is sometimes difficult to determine whether or not a stocking project has been successful. The species with which to stock is dependent upon the stocking goal. Brown trout are more difficult to catch than either brook or rainbow trout and may be suitable for the angler who enjoys a challenge as opposed to easy prey. The life span of brown trout is also longer than the other two previously mentioned trout species and may be able to contribute to a fishery for a longer period of time. In 1983, rainbow trout was the most frequently stocked species (78% of total), with brook trout being the second (11%) and brown trout the third (10%).

HEIKINHEIMO, O. and J. RAITANIEMI. 1998. Decision analysis as a tool in planning fisheries management, exemplified by the whitefish and brown trout fishery in Lake Lappajaervi, Finland. Proceedings of the Sixth International Symposium: Biology and Management of Coregonid Fishes – 1996. Advances in Limnology 50 : 401-417.

In Finnish inland waters, brown trout (*Salmo trutta lacustris*) stocking often yields low catches if there is gill net fishing for whitefish (*Coregonus lavaretus*) in the same lake. A great deal of brown trout young are taken as a by-catch with gill nets of small mesh sizes when still below the allowable catch size (40 cm). On the other hand, mesh size restrictions for gill nets may lead to underexploitation of whitefish. In Lake Lappajaervi, whitefish are mostly caught by professional fishermen with gill nets and pound nets, while 45-70% of the brown trout catch is taken by recreational fishermen with gill nets and rods. In order to determine the optimal policy for obtaining the maximum benefit of whitefish and brown trout stocking, we compiled an influence diagram and applied decision analysis. The decision variables in the model were mesh size restriction for gill nets, fishing effort with gill nets and pound nets, and stocking size for brown trout. The data needed for calculating the total benefit consisted of growth data, fishing and natural mortalities, catchabilities by age-group, prices paid to fishermen for the catches, and market prices for the stocking material of both species. The recreational value of brown trout fishing was taken into account as a coefficient of the price of the brown trout catch. According to the decision analysis, the smallest allowable mesh size of gill nets should be 55 mm and the fishing effort should be lower than it is at present. Pound net fishing is advantageous if the whitefish grow slowly, but in the case of rapid whitefish growth, pound net fishing would decrease the economic benefit from stocking. If there was no fishing with pound nets, the minimum mesh size for gill nets should be lower in periods of slow whitefish growth to ensure the profitability of whitefish stocking.

HELFRICH, L. A. and W. T. KENDALL. 1982. Movements of hatchery-reared rainbow, brook and brown trout stocked in a Virginia mountain stream. Progressive Fish Culturist 44 : 76-80.

During May, 1979, 1,061 catchable-sized, hatchery-reared rainbow trout (*Salmo gairdneri*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*) were tagged and stocked in pool and riffle habitats in Big Stony Creek, Giles County, Virginia. Of this total, the movement patterns of 275 recovered trout were determined through voluntary tag return and creel census information. Most (75%) of the trout were recovered within 1 km of their respective release sites; 16% remained within the initial stocking location. Most of the recaptured brook trout (69%) and rainbow trout (59%) were recovered downstream, whereas brown trout (69%) moved primarily upstream. The median dispersal distances for brook trout (195 m downstream) and rainbow trout (60 m downstream) were not significantly different from one another, but were significantly different ($P < 0.001$) from brown trout (90 m upstream). Although trout stocked in pools generally exhibited less movement than those stocked in riffles, the type of stream habitat into which the trout were introduced had no significant effect on the distance or direction of dispersion of the three species.

HENRY, G. 1997. Further stocking successes by the New South Wales Fisheries. Fisheries New South Wales 1 (Summer) : 31-33.

Enhancement of fish populations through stocking programs began in the nineteenth century as Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) were introduced to Australia from Britain. Stock enhancement programs have a number of advantages for fishery resources, recreational fishers and the fish farming industry in New South Wales. Millions of fish have been bred and released into more than 100 impoundments that were constructed over the years for agriculture, industry and water supply in New South Wales. Popular recreational fisheries have been created and many of these stocked impoundments now support regional economies based on tourism and fishing. Stock enhancement programs have also been initiated to improve fishery resources which have been reduced by environmental degradation or overfishing as rivers have been subjected to a range of environmental stresses from irrigation, agriculture, dredging, desnagging and the introduction of pest species.

HERMAN, M . P. 1997. Use of Floy tags to determine angler harvest of brown trout in two southern Michigan streams. Fisheries Technical Report No. 97-1. Michigan Department of Natural Resources. Lansing, Michigan. (Abstract only)

In late March 1991, 50% of the yearling brown trout stocked into the St. Joseph-of-the-Maumee River and 63% of those stocked in the South Branch of the Kalamazoo River were marked with Floy tags in an effort to estimate the angler harvest. St. Joseph River anglers returned a total of 31 tags representing an estimated minimum harvest of 1.6%. Factors that could have contributed to the observed low number of tag returns include tag loss (or shedding) after stocking, high hooking mortality of sublegal tagged fish, mortality due to tagging, natural mortality of tagged trout before they reached legal size, tags not returned by anglers and migration of fish out of the stocked areas. Tag loss and migration of stocked trout was probably very high throughout this study. Thus, angler returns of Floy tags did not yield reliable estimates of angler harvest. These estimates have limited value since they are based on a small number of returned tags and harvest was likely underestimated. Using larger trout may result in improved tag retention and is recommended for future tagging studies.

HERMANSEN, H. and C. KROG. 1984. Influence of physical factors on density of stocked brown trout (*Salmo trutta*) in a Danish lowland stream. Fisheries Management 15(3) : 107-116.

Physical factors and brown trout densities were studied in a small Danish lowland stream. The densities of brown trout larger than 15 cm were significantly correlated with gradient, mean depth, coefficient of variation in current velocity 7 cm above the bottom, the ratio between wetted perimeter and width, amount of overhanging banks and degree of macrophyte cover. Coefficient of variation in current velocity 7 cm above the bottom was the most important factor for brown trout density ($r_s = 0.8364$, 24 df ($P \leq 0.001$)), which supports the idea of this value as a measure of stream complexity. A rather small relation between trout density and amount of overhanging bank cover ($r_s = 0.4179$, 24 df ($P \leq 0.050$)), contrary to the closer relationships found in previous studies, it is discussed as an effect of the self-shading capacity of this rather narrow and deep stream.

HESTHAGEN, T., L. FLOYSTAD, O. HEGGE, M. STAURNES and J. SKURDAL. 1999. Comparative life history characteristics of native and hatchery-reared brown trout (*Salmo trutta*) in a sub-Alpine reservoir. Fisheries Management and Ecology 6(1) : 47-61.

Wild and non-native, hatchery-reared brown trout (*Salmo trutta*) released when 2 summers old, were caught in the littoral habitat of Vinstervatna Reservoir, southern Norway. Hatchery-reared brown trout grew more slowly and had a smaller asymptotic length (293 ± 71 mm CL) than native fish (391 ± 56 mm CL). Hatchery-reared brown trout also exhibited significantly shorter life spans than native fish. This category consisted mainly of individuals aged 2+ and 3+ years, and only 1.5% of the specimens were aged ≥ 5 years. The ages of the native fish in the sample were between 2 and 8 years, and the most abundant age groups of trout were 4+ and 5+ years. It is suggested that the differences in life-history characteristics are related to adaptations by the native trout to the local environmental conditions. In this reservoir, which has a limited food supply as a result of water level fluctuations and a high level of inter- and intraspecific competition, environmental effects might be significant.

HESTHAGEN, T. and O. HEGGE. 1992. Standing of pond- and hatchery-reared juvenile brown trout (*Salmo trutta*) during draw down of a pond. Aquaculture and Fisheries Management 23(3) : 399-403.

One thousand each of pond- and hatchery-reared 0+ brown trout (*Salmo trutta*) were fin-clipped and released in a 1300 m^2 large earthen pond. The pond was drawn down 5 days after the introduction, and descending individuals were caught in a trap at the outlet. A total of 904 pond-reared and 890 hatchery-reared fish were recaptured (i.e. a loss of 9.6 and 11.0%, respectively). A total of 25 pond-reared and 16 hatchery-reared fish were recorded as being stranded in the pond during the draw-down, accounting for 2.7 and 1.8% of total recoveries.

Pond-reared fish descended significantly earlier than did hatchery-reared fish. Most individuals descended during the first 4.5 hours (75-83%). However, the final recoveries were made 10 days (233 hours) after the first descent.

HESTHAGEN, T., O. HEGGE, J. SKURDAE, and B. K. DERVO. 1995. Differences in habitat utilization among native, native stocked, and non native stocked brown trout (*Salmo trutta*) in a hydroelectric reservoir. Canadian Journal of Fisheries and Aquatic Sciences 52(10) : 2159-2167.

Native and native-stocked brown trout (*Salmo trutta*) in Lake Tesse, a regulated hydroelectric reservoir (southern Norway), were spatially segregated according to size: small individuals occurred mainly in the epibenthic habitat and larger individuals mainly in the pelagic habitat. In contrast, all size groups of non-native stocked brown trout were mostly restricted to the epibenthic habitat. Age-specific lengths were generally larger for non-native than for native-stocked trout, which were larger than native fish. However, growth rate between age 3 and 4 was significantly lower for non-native stocked fish than for native and native stocked fish. Differences in body length were mainly due to strain but also to some extent to habitat conditions. Native fish had significantly fuller stomachs in the pelagic than in the epibenthic habitat in the summer. Epibenthic non-native fish had significantly fuller stomachs than native and native-stocked fish in August but not in July. Native and native-stocked fish fed mainly on surface insects and planktonic crustaceans in both habitats. We hypothesize that the non-native brown trout stocked in Lake Tesse do not use the pelagic habitat in the home lake and are therefore less adapted to utilize such habitat than populations originating from lakes where pelagic habitat is available.

HESTHAGEN, T. and B. O. JOHNSEN. 1989$_a$. Lake survival of hatchery and pre-stocked pond brown trout (*Salmo trutta*). Aquaculture and Fisheries Management 20 : 91-95.

A comparison was made of lake survival, after 2 years, of hatchery and pre-stocked pond brown trout (*Salmo trutta*) (age 0+) in two small mountain lakes in south-central Norway, one which contained a resident population of brown trout. There was a significantly higher recapture rate of pond fish in both lakes. The mortality rate for the stocked fish was significantly higher in the lake which contained a resident population of brown trout. The competitiveness of the stocked fish is discussed in relation to foraging success, predation and stress.

HESTHAGEN, T. and B. O. JOHNSEN. 1989$_b$. Survival and growth of summer- and autumn-stocked 0+ brown trout (*Salmo trutta*) in a mountain lake. Aquaculture and Fisheries Management 20 : 329-323.

In the present study conducted in a Norwegian mountain lake, we tested whether there was any seasonal effect on survival and growth of 0+ brown trout stocked in the summer and the autumn respectively. The study was conducted in Lake Fjellokkertjern, a small (12 ha), strongly oligotrophic water with most depths between 2 and 4 m. The stockings were carried out in 1984 using brown trout of the Bjornesfjord strain which were reared at Reinsvoll hatchery. The fish were hatched and start-fed in heated water and two groups of 250 specimens were released in Lake Fjellokkertjern on 13 July and 29 September, respectively.

The study showed a significantly higher survival of brown trout stocked as summerlings compared with autumn fingerlings in this mountain lake. We did not find any significant difference in growth rates of back calculated or observed lengths between summer and autumn released fish. By the end of the first growing season, summer-stocked fish had attained a length (66 mm) close to that of the autumn stocked fish (69 mm).

HESTHAGEN, T. and B. O. JOHNSEN. 1992. Effects of fish density and size on survival, growth and production of hatchery-reared brown trout (*Salmo trutta*) in lakes. Fisheries Research 15(1-2) : 147-156.

Four small lakes (0.9-7.5 ha) were each stocked with 500 individually tagged, one year old hatchery-reared brown trout (*Salmo trutta*) corresponding to densities of between 67 and 250 fish ha^{-1}. The lakes were treated with rotenone one year before stocking to eliminate pike (*Esox lucius*). Population estimates were carried out 14 months after stocking by the removal method, using a series of standard gill nets during two successive nights. No recaptures were obtained in a lake which still harboured adult pike. Population estimates in the three lakes ranged from 101 to 249 specimens, corresponding to survival rates of 0.2-0.5. The survival rates were positively related to initial stocking density. Both recapture rate and length at recapture were significantly correlated with initial fish length. Mean length at recapture as well as back calculated length at age of 2 years exhibited a negative relationship to fish density at the end of the study period. The greatest production (30.88 kg ha^{-1}) was obtained in the lake stocked at the highest rate (250 fish ha^{-1}). A higher growth rate in the lake with less fish could only partially compensate for slower growth in the more densely populated lakes. Hence, production in the lakes was limited by factors affecting survival.

HILL, M. T. and W. S. PLATTS. 1998. Ecosystem restoration: A case study in the Owens River Gorge, California. Fisheries 23(11) : 18-27.

In 1991, the Los Angeles Department of Water and Power, in cooperation with Mono County, California, initiated a multiyear effort to restore the Owens River Gorge. The project aims to return the river channel, dewatered for more than 50 years, to a functional riverine-riparian ecosystem capable of supporting healthy brown trout and wildlife populations. The passive, or natural, restoration approach focused on the development of riparian habitat and channel complexity using incremental increases in pulse (freshet) and base flows. Increasing pulse and base flows resulted in establishment and rapid growth of riparian vegetation on all landforms, and the formation of good-quality microhabitat features (pools, runs, depth, and wetted width). An extremely complex, productive habitat now occupies the bottom lands of the Owens River Gorge. A healthy fishery in good condition has quickly developed in response to habitat improvement. Brown trout numbers have increased each year since initial stocking, 40% between 1996 and 1997. Catch rates increased from 0 fish/hour in 1991 to 5.8-7.1 fish/hour (with a maximum catch rate of 15.7 fish/hour) in 1996.

HOFMAN, E. L. 1989. The effect of various stocking factors on survival of lake trout and brown trout: A selected review. Draft. Fish Culture Section, Ontario Ministry of Natural Resources. Toronto, Ontario. 28 p. + appendices.

Through an examination of planting studies, the author has made several conclusions concerning brown trout stocking:

- The stocking of fall fingerlings gives poor returns in inland lakes and the Great Lakes.
- The strain which is stocked may be important. When stocked into the Hoosic River, a tributary of the Hudson River, the selectively bred Rome strain produced greater than twice the return of the less intensively selected Catskill strain (11.7% versus 3.3%, and 8.1% versus 4.7%, respectively, for two plantings).
- It was determined that the survival of stocked 2+ brown trout from winter to spring increased through the seasonal plantings, while summer to fall plantings decreased over the course of the two seasons.
- There currently exists controversy over the suitability of stocking sites and stocking methods. Stream planted brown trout may experience greater survival when spot planting was employed.

HOLCOMB, D. E. 1964. A history of intentional introductions of exotic fishes in Michigan. M. Sc. Thesis, University of Michigan. Ann Arbor, Michigan. 33 p.

Between 1872 and 1941, at least 16 species of exotic fishes were introduced into the waters of Michigan, primarily through the efforts of the United States Fish Commission and the Michigan Fish Commission. This paper attempts to compile information concerning these introductions, delineating the early history of the responsible agents, and their attempts to establish these exotics.

The brown trout, native to Europe, was first introduced in the 1880s to the United States. Present day populations originated from two separate stocks. The European brown trout (*Salmo fario*) came from Germany, while the Loch Leven brown trout (*Salmo leveninsis*) came from Scotland. Both were though to be related as subspecies, but the extent of mixing which occurred in the hatcheries when the fish was first shipped to the United States has resulted in the inability to distinguish either strain in America. The first shipment of brown trout eggs found their way to the Mumford Hatchery, run by the New York Fish Commission. It was stated by Herr Von Behr, who made the shipment, that although the eggs were of different sizes, they belonged to the same species. The larger eggs came from trout which lived in deep lakes and the smaller ones from trout inhabiting mountain streams. Many more introductions were made in the 1880s.

Since its introduction, the brown trout has been planted continuously by both the federal government and the State of Michigan. The records of the Michigan Commission show that 89,239,166 were planted in sixty-one different years, from 1885 to 1961.

HOLLOWAY, A. D. and T. K. CHAMBERLAIN. 1942. Trout management and stocking results in the southern Appalachians. p. 245-249. *In* Transactions of the 7th North American Wildlife Conference, April 8-10, 1942, Toronto, Ontario.

In 1934, the U. S. Bureau of Fisheries made the first stream surveys in the National Forests of North and South Carolina, Georgia and Tennessee. These surveys were later extended to all trout waters by the Forest Service under the supervision of the U. S. Bureau of Fisheries. In 1937, the Pisgah National Game Preserve and the Sherwood Cooperative Wildlife Management Area were designated as experimental areas for trout management. On these the biologists of the U. S. Fish and Wildlife Service have conducted investigations for the past five years. This is a cooperative project between the two federal bureaus and the North Carolina Division of Game and Inland Fisheries.

In 1936, in one management area 586 anglers caught 1,017 trout (rainbow, brook and brown) or an average of 1.7 per fisherman day. By 1941, the areas had increased to 16, the fishermen days to 11,076, the average catch to 5.9 per fisherman day, and the estimated total catch on all areas to 65,000 fish weighing 11,700 pounds.

Brown trout made up 2% of the total catches in the managed waters during 1941. With this species we are still in the experimental stage. In streams with a low quantity of bottom fauna, an abundant population of forage fish and suitable temperatures as occurs in certain sandy streams in South Carolina and Georgia, brown trout appear to have a definite place in our trout program.

Records from three fall plantings of 5,330 brown trout, 5 to 7 inches in length, in Mill River on the Pisgah National Game Preserve show a recovery of 10.6% for the first fishing season; from two plantings of 3,830, 4.8 the second season; and from one planting of 1,500, 1.1 the third season. From two spring plantings of 2,690 fish between 7 and 9 inches in length a recovery of 14.4% was secured the first season and from one planting the second season of 1,870, 4.3%.

HOSMER, M. J. 1980. Handling as a factor in mortality of trout with or without furunculosis. Progressive Fish Culturist 42(3) : 157-159.

Mortalities of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*) in 1978 and 1979 were significantly higher in clinically diseased than in subclinically diseased or healthy fish in both years. Mortalities in diseased fish within 24 hours after sampling were not statistically different from those in specific-pathogen-free controls; however, the crowding of fish lots for stocking resulted in significantly higher mortalities in furunculosis-infected brown trout in 1979. Crowding and handling for stocking thus caused higher mortality in diseased fish than just sampling. Healthy trout were able to tolerate more handling stress.

HULBERT, P. J. 1985. Post-stocking performance of hatchery-reared yearling brown trout. New York Fish and Game Journal 32(1) : 1-8.

Two genetic lines of brown trout are maintained for general production purposes in the Department of Environmental Conservation's propagation system. The Rome strain has been selectively bred for resistance to furunculosis over three decades, whereas the Catskill strain has not undergone intensive selection since its origin in 1949. Differences in post-stocking performance of yearling fish from these broodstocks were studied in the Hoosic River through creel censuses and electrofishing surveys. The Rome strain fish were significantly more numerous in both the angler catches and electrofishing samples, indicating that they survived better than the Catskill fish. These results suggest that one strain may be better adapted than the other for stocking various waters.

HULBERT, P. J. and R. ENGSTROM-HEG. 1980. Hooking mortality of worm-caught hatchery brown trout. New York Fish and Game 27(1) : 1-10.

The mortality of sub-legal brown trout taken by angling (in New York) with worm-baited hooks of five different sizes was investigated, using age 1+ hatchery-reared fish released in late spring in a small pond. Comparable numbers were handled with wet or dry hands, and the hooks were removed manually, except that for some that had been deeply hooked the leaders were clipped. The fish were then held in aquaria together with control fish for 14 days and their mortality was recorded. The data were analyzed according to whether the fish had been lightly hooked or deeply hooked. Two-thirds of the trout taken were lightly hooked and their mortality (0.9%) was not significantly different from that of the controls. For deeply hooked trout, the mortality was 59% when the hooks were removed but only 18% when the leaders were clipped. The data suggest, that for all trout taken, the short term mortality would have been about 22% if all hooks had been removed but only about 7% if the leaders had been clipped on all the deeply hooked fish. Handling with wet or dry hands had little effect on mortality. The leader-clipped specimens that survived the initial test period were held over the summer and, while additional mortality occurred, all fish surviving the summer were able to feed and grow.

HULBERT, P. J. and R. ENGSTROM-HEG. 1982. Upstream dispersal of fall-stocked brown trout in Canajoharie Creek, New York. New York Fish and Game Journal 29 : 166-175.

A large proportion of fall-stocked fingerling brown trout in Canajoharie Creek consistently dispersed upstream within a few days after stocking. Subsequent sampling in the immediate vicinity of the release sites would have given misleadingly low estimates of survival. If this is a general pattern of behavior for fingerling brown trout stocked in the fall, it should be considered in connection with the stocking of these fish and in evaluating their contribution to trout fisheries.

This study assessed the impact of restrictive angling regulations that emphasize release of most trout caught on a stocked brown trout (*Salmo trutta*) fishery. It is the first completed evaluation of deliberately imposed catch-and-release regulations in Wisconsin that provides field data on both the sport fishery and the trout populations. Angling regulations imposed were the use of artificial flies and lures only, a minimum length limit of 13 inches, and a daily bag limit of one trout. Assessment procedures involved a partial season-long creel census and spring and fall trout population estimates during a 4-year period, the first year (1976) under normal statewide angling regulations and the following three years under the special regulations.

Parallel data were also obtained from a reference zone where statewide regulations prevailed throughout the entire 4-year period.

The catch-and-release fishery was judged to be highly successful.

- Angler use remained high in comparison to that during the 1976 baseline season; there was a 5% reduction in angler hours but angler trips/season increased by an average of 15%. Angler use during 1977 amounted to 1,015 hours/acre, the highest known value on a Wisconsin trout stream.
- Harvest was reduced by 99%, while the number of trout released increased by 116%. The 3-season average of trout released to trout creeled was 268:1 as compared to a ratio of 2:1 in 1976.
- Some trout were probably released more than once per season since the catch of trout creeled or released exceeded the number present in April.
- In response to the catch and release regulations, more anglers fished 10-20 times/season and the frequency of releasing more than 10 trout/trip increased.
- Distribution of angling effort over the course of the season was more even.
- The combined catch rates (trout creeled or released) increased to atypically high values for Wisconsin – from 0.8/hour in 1976 to 1.08, 1.46, and 1.48 in 1977-79.

Abundance, biomass, and survival rate characteristics of trout all changed favorably, based on average values for 1977-79 vs. 1976 data. The number of I+ trout increased in April by 58% (to 3,379/mile) and April biomass increased by 46% (to 164 lb/acre). April to October survival of I+ trout averaged 56% during the special regulation seasons vs. 39% survival in 1976.

Abundance of trout over 13 inches in early October (week after close of the fishing season) increased an average of only 12%. The successful catch-and-release fishery that evolved was not augmented by a much-improved "trophy trout" fishery. Lack of suitable habitat for such trout may have been the principal factor preventing a greater buildup. Removal of trout over 13 inches by anglers was not a limiting factor preventing a sustained accumulation in the population.

The findings support continuation of the special regulations on the Race Branch as a highlight feature of trout management in that region and a modest expansion of catch and release regulations to other trout streams in Wisconsin to further diversify the variety of trout angling opportunities and strengthen the "management for quality" concept that is a basic component of present Department of Natural Resources trout management policy.

HUNER, J. V. and O. V. LINDQUIST. 1983. How Finland stocks her rivers. Fish Farming International 10(4) : 10-11.

The production and stocking of fry and fingerlings of high value species is an important part of Finland's fisheries program. Species of particular importance are whitefish (*Coregonus*), northern pike (*Esox lucius*), Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*). Fry and fingerlings are produced both by private interests and government.

IKONEN, E. and H. AUVINEN. 1982. Results of Finnish stocking with sea trout (*Salmo trutta*) in the Baltic Sea in 1971-1980. International Council for the Exploration of the Sea, Council Meeting 39. 13 p.

ILLINOIS DEPARTMENT OF NATURAL RESOURCES. 1998. Fish stocking policy. Illinois Department of Natural Resources. Springfield, Illinois. 8 p.

Lake Michigan holds the only suitable trout habitat in all of Michigan. Annual stocking is, however, required to maintain these populations. It is anticipated that 50,000 brown trout fingerlings will be stocked into the Illinois waters of Lake Michigan. At this time no other waters may be stocked with rainbow or brown trout without the explicit permission of the central office. The State hatchery system has two sizes of brown trout available for stocking. In May, those measuring four inches (spring fingerlings) and in September-October those measuring ten inches (fall fingerlings) will be ready for stocking purposes.

JOHNSEN, B. O. and T. HESTHAGEN. 1990. Recapture of pond and hatchery-reared brown trout (*Salmo trutta*) released in small streams. Aquaculture and Fisheries Management 21 : 245-252.

Two groups of 0+ brown trout (*Salmo trutta*), one pond-reared and one hatchery-reared (fish length 32-80 mm), were released in eight small streams in three different areas of Norway between 1984 and 1987. Hatchery and pond fish were reared at different sites but releases were made both near the rearing site and in the home area of the other group. A total of 2,550 fish were recaptured by electrofishing the year after stocking. We found great variations in the recapture rates of pond and hatchery fish in one stream between years and between streams in different areas the same year. These results indicate that the rearing method is not essential to the recapture rate. Both pond and hatchery fish generally had higher recapture rates in streams near their rearing site than in the distant areas. Thus factors associated with transportation seem to influence the survival of stocked fish. The results also indicate that size at stocking may be an important factor for the recapture rate.

JOHNSEN, B. O. and O. UGEDAL. 1986. Feeding by hatchery-reared and wild brown trout (*Salmo trutta*) in a Norwegian stream. Aquaculture and Fisheries Management 17 : 281-287.

Hatchery-reared brown trout (*Salmo trutta*) yearlings were captured shortly (3 hours to one week) after their release in a Norwegian stream. The feeding of recaptured hatchery fish was compared with that of wild brown trout. The investigations were carried out during three different periods (May, July and October). Investigations of drift fauna indicated that food availability was best in May. Most hatchery-reared brown trout started feeding shortly after their release in all three periods. Hatchery fish went through a learning process with respect to feeding. This was most clearly demonstrated by the amounts of plant fragments in their stomachs, which were always greater in hatchery fish than in wild fish but which decreased with time after release in hatchery fish stomachs in all three periods. By about one week after release hatchery trout appeared to be feeding on wild prey nearly as well as did wild fish, but they achieved this better in May than in October.

JOHNSEN, B. O. and O. UGEDAL. 1988. Effects of different kinds of fin clipping on overwinter survival and growth of fingerling brown trout (*Salmo trutta*) stocked in small streams in Norway. Aquaculture and Fisheries Management 19 : 305-311.

Nine thousand fingerling (0+) brown trout (*Salmo trutta*) (size 50-90 mm) were fin clipped in six different ways and released in small streams in September 1984 and 1985. A total of 2,625 fish were recaptured by electrofishing the year after stocking. Differences in survival between fin clip groups were found in one out of eight stockings. No growth differences were found among the several groups. Pectoral and anal fins regenerated most, while adipose fins regenerated least. Single fin clipping is a recommended marking method for fingerling brown trout during short term studies. Multiple fin clips may result in lower survival. Regeneration of fins, especially pectoral and anal fins, make the clipping of these fins less adapted to long term investigations.

JOHNSEN, B. O. and O. UGEDAL. 1989. Feeding by hatchery-reared brown trout (*Salmo trutta*) released in lakes. Aquaculture and Fisheries Management 20 : 97-104.

Shortly after their release in two Norwegian lakes (3 hours to 3 weeks), hatchery-reared brown trout (*Salmo trutta*) yearlings were recaptured, and their feeding was compared with that of wild brown trout. Investigations were conducted during three different periods (June, August and September). In all three periods most of the hatchery-reared fish started feeding immediately after their release. The amounts of exuviae from Ephemeroptera larvae and Chironomidae pupae found in the stomachs of hatchery-reared trout decreased with time, indicating that their feeding habits were influenced by a learning process. However, within one week of their release, hatchery trout appeared to be feeding on wild prey as well as did wild fish.

JOHNSEN, B. E. and O. UGEDAL. 1990. Feeding by hatchery- and pond-reared brown trout (*Salmo trutta*) fingerlings released in a lake and a small stream. Aquaculture and Fisheries Management 21 : 253-258.

Fingerling (0+) brown trout (*Salmo trutta*) pond-reared on natural food or hatchery-reared on artificial food started feeding immediately following their release into a lake or a stream. There was no difference in feeding ability between the hatchery and the pond-reared fish.

JOHNSON, J. E., D. SMITH and J. BAKER. 1998. Predation by walleye on stocked salmonids in Lake Huron. *In* Proceedings of the 59th Midwest Fish and Wildlife Conference, December 7-10, 1997, Milwaukee, Wisconsin. (Abstract only)

More than 90% of trout and salmon harvested from Michigan waters of Lake Huron are of hatchery origin. The objective of this research was to identify causes of declining post-stocking survival, which threatened the sport fishery and economic viability of stocking. Predator fish were sampled in beach zones and river mouths at times and locations where stocking occurred. From 1990-1996, stomachs of 1,054 predator fish, mostly walleyes, were examined to record consumption of stocked fish. At a brown trout stocking site, yearling brown trout composed 4% of the walleye diet. At other sites combined, chinook and steelhead smolts averaged 31% and 9%, respectively, of the walleye diet. Chinook smolts composed 22% of the diet of lake trout sampled in the beach zone. In 1992, stocking dates for steelhead and brown trout were delayed to correspond with peak abundance of alewives and return to creel subsequently increased nearly 250%. Returns of chinook acclimated in receiving waters using rearing pens were higher than for chinook planted using conventional means. Conclusions: (1) Stocking during the alewife spawning period may enhance survival by offering abundant alternative prey; and (2) pen culture shows promise for minimizing predation during acclimation and imprinting of smolts.

JOHNSON, M. W. 1978. Management of lakes for stream trout and salmon. Special Publication No. 125. Minnesota Division of Fish and Wildlife. St. Paul, Minnesota. 65 p.

The brown trout has not been introduced or stocked in Minnesota to the extent of the brook and rainbow trout. They are more tolerant of warm water than rainbow trout, but return less fish to the creel when stocked in equal numbers. They are more difficult to catch than rainbow trout, yet have a greater survival to larger size. Brown trout are highly piscivorous and it is suspected that the species may be responsible for failure of rainbow trout stockings in California.

Brown trout are seldom used in Minnesota lakes and there is little information available on their post-stocking performance. It is cautiously recommended that they be stocked using the rates designated for rainbow trout. These include using small, medium and large fingerlings, as well as yearlings, and stocking according to expected fishing pressure and water type (i.e. hardwater, softwater, winterkill lake etc.).

JOHNSON, M. 1983. An evaluation of stream trout stocking in Langlade, Lincoln and Marathon counties. Fisheries Management Report 114. Wisconsin Department of Natural Resources. Madison, Wisconsin. 7 p.

Thirteen streams in Langlade, Lincoln and Marathon counties were surveyed during a 6-year study to determine the survival of stocked hatchery fish. Single-run electrofishing surveys revealed an average survival rate of 1.7% for yearling brook trout and 11.3% for yearling brown trout after 60 to 120 days in the stream.

A stratified creel census on two streams showed an angler harvest of 43% to 68% for stocked brook trout and 35% to 64% for stocked brown trout. More than 75% of the harvest occurred in the first month of the trout fishing season, and a major portion of the harvest occurred opening weekend. About 32% to 40% of the stocked brook trout and 27% to 60% of the stocked brown trout were not recovered by stream shocking, presumably because of natural mortality.

JOHNSON, R. E. and L. HINER. 1947. Survival of spring-planted yearling and fall-planted fingerling brown trout in the South Branch of Whitewater River and Gilmore Valley Creek, Winona County, Minnesota, as determined by creel census and electroshocker. Fisheries Investigation Report No. 73. Minnesota Department of Natural Resources. St. Paul, Minnesota. 54 p.

Laurence Hiner and crew shocked 26 stations on the South Branch between June 27 and July 13, 1946, to determine the trout population of the region and the survival and welfare of marked fish planted in April.

Of the 26 stations, 5 are not considered in this summary because they fell far outside the stream sectors habitable by trout. The 21 remaining ranged from 270 to 752 feet in length, and from 6,612 to 25,915 square feet in area, including pools and riffles in each section. Total length of stream habitable by trout is figured at 11.2 miles, of which almost 2 were tested. About 17% of the total length was shocked. Total area shocked was 289,039 square feet, or 6.6 acres.

In this area of trout stream, 118.93 lbs. of trout were recovered, including 264 browns and 2 brooks. 617 brown trout had been recovered in the fishery. This is at the rate of 18.02 pounds per acre.

Of the 264 brown trout, 74.2% (196) were clipped trout released just a few weeks previously. The other 68 (25.8%) were unclipped browns mostly of larger size. On the basis of the total trout area, this is 10.7% survival of the 10,780 fish planted in Whitewater. On these dates, there remained about 100 trout per mile of stream, in place of the 1,000 or more known to be there when the season opened.

The trout captured by shocker had moved 1.2 miles upstream above highest point of planting, and 1.5 miles down, in about 10 weeks.

The average coefficient of condition of 25 marked fish was computed at 41.1, compared with 38.9 at the time of planting. It is apparent that the fish lost little weight immediately after planting and gained weight rapidly thereafter.

At time of planting, average length of 100 planted fish was 7.0 inches. At time of recovery by shocking, average length of 181 fish was 8.6 inches, a gain of 1.6 inches in 2.5 months.

JOHNSSON, J. I., E. PETERSSON, E. L. JONSSON, B. T. BJORNSSON and T. JÄRVI. 1996. Domestication and growth hormone alter antipredator behavior and growth patterns in juvenile brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences 53 : 1546-1554.

In the hatchery environment, there is no selection by predators against risky foraging behaviour and excessive aggressiveness. Consequently, hatchery-reared trout should have a higher competitive ability and a less pronounced antipredator response than wild trout. Growth hormone increases the energy demand and thereby the feeding motivation of an animal. Therefore, growth hormone injections should reduce the antipredator response and promote competitive ability. Both hatchery selection and growth hormone injections consistently reduced antipredator behavioural responses in juvenile brown trout (*Salmo trutta*) in the presence of a trout predator. However, neither hatchery selection nor growth hormone had any effect on dominance or quantity of contested food consumed, whereas both hatchery selection and growth hormone injection promoted growth. RNA levels were increased by growth hormone and hatchery-reared trout had lower RNA levels than wild trout. The presence of the predator increased RNA levels in the trout independent of strain and treatment. Our study suggests that antipredator behaviour, growth rate, and resource allocation patterns in brown trout change rapidly as a consequence of hatchery selection and that similar changes in antipredatory behaviour can be induced by increasing GH levels. Thus, released or escaped hatchery-reared fish or fish with manipulated growth hormone levels with altered behaviour patterns may pose a potential threat to wild populations.

JOHNSTON, T. B. 1979. Catchable trout – a consensus needed. Fisheries 4(5) : 14-15.

The past ten years have seen an increase in the stocking of adult trout over sub-catchables. Annually, greater than 70 million brook, rainbow and brown trout are stocked into American waters. The lack of common values among fisheries managers can lead to over-stocking, and creating artificial fisheries in areas where the costs outweigh the benefits. A lack of knowledge can also negatively impact the public's attitude towards angling. It is strongly suggested by the author that attempts be made to assemble all available information concerning the results of catchable trout programs country-wide. Analysis of these results will allow the formulation of guidelines surrounding catchable-trout programs. Finally, sociologists should be consulted to minimize any adverse sociological impacts of catchable-trout programs.

JOHNSTONE, A. D. F., A. F. WALKER, G. G. URQUHART and A. E. THORNE. 1995. The movement of sea trout smolts (*Salmo trutta*) in a Scottish west coast sea loch determined by acoustic tracking. Scottish Fisheries Research Report No. 56. The Scottish Office of Agriculture, Environment and Fisheries Department. 21 p.

The movements of sea trout (*Salmo trutta*) post-smolts were observed in the sea by tracking fish fitted with small ultrasonic transmitters (70-86 kHz). Twelve sea trout smolts, obtained from locals rivers, were manually tracked in Loch Ewe on the west coast of Scotland.

Three smolts returned to fresh water within a few hours of release. The remaining smolts were continuously tracked for periods of up to 68 hours and one was followed intermittently for over 10 days. The smolts generally remained in shallow water in the littoral and immediate sub-littoral zones within 1.5 km of the river mouth. One tagged smolt remained close inshore for a period of over 50 hours before moving across open water to a bay at the mouth of Loch Ewe about 6 km from its release position. Swimming speeds for this smolt, corrected to allow for the effects of tidal flow, were estimated to be between 5.9 cm/second and 25.4 cm/second.

JOHRI, V. K. and R. PRASAD. 1989. Impact of the introduction of *Salmo trutta fario* and *Salmo gairdneri* in Garhwal Himalayas. p. 83-84. *In* Exotic Aquatic Species in India. Special Publication of the Asian Fisheries Society, Indian Branch No. 1.

The brown trout (*Salmo trutta fario*) was introduced in Garhwal Himalayas in 1910. It was propagated and its seed was stocked in Himalayan river streams and upland lakes. It has successfully established itself in Deodital Lake located at an altitude of about 3,000 m in central Himalayas, where it breeds naturally during the onset on winter when water temperature is about 5° C. Deodital appears to be the only lake in Garhwal Himalayas where trout has naturally established itself. A brown trout population is also available for angling in the upper reaches of snow-fed Bhagirathi River system. The rainbow trout (*Salmo gairdneri*) has been introduced into Garhwal Himalayas by the State fisheries department recently at the Kaldyani trout hatchery in Uttarkashi district and Talwari trout hatchery in Chamoli district.

JOKIKOKKO, E. 1990. Brown trout stockings in the restored rapids of the tributaries of the river Oulujoki system in eastern Finland. Polskie Archiwum Hydrobiologii 38(1-2) : 79.

The rivers Piispajoki and Mustajoki flow into Lake Kiantajaervi, the largest lake in the upper part of the River Oulujoki water system, which empties into the Bothnian Bay. All rapids in the rivers Piispajoki and Mustajoki were dredged by bulldozers for timber floating in the 1950's. The rivers Piispajoki and Mustajoki were restored in 1979 by pushing dredged stones back into the rapids. Because the original brown trout (*Salmo trutta*) stock had died out, trout fry were stocked annually in the rapids since the restoration. Electrofishing showed that the brown trout populations recovered in both rivers after stocking. However, after the fry stockings had terminated, the brown trout disappeared almost completely within two years, due to lack of natural reproduction in the rapids.

JOKIKOKKO, E. 1999. Density of brown trout (*Salmo trutta*) and Atlantic salmon (*S. salar*) parr after point and scatter stocking of fry. Fisheries Management and Ecology 6(6) : 475-486.

Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) fry were point- and scatter-stocked in the early part of June at densities of 63–263 fry/100 m^2 per species in the River Viantienjoki, a small river in northern Finland, and their population densities were assessed in late summer. Both species were always stocked together in similar quantities. Point stocking was used in the first 2 years and scatter stocking in the following 2 years. In point stocking, there was no correlation between the distance from the stocking sites (maximum = 250 m) and parr density in census sites (r=0.013 and 0.019 for brown trout and Atlantic salmon, respectively). The stocking density of fry did not influence parr density in August by either method or by species. Stocking density explained only from 11% to 23% of the parr survival depending on the species or stocking method. The mean densities of Atlantic salmon and brown trout parr did not differ significantly from each other at any fishing site ($P > 0.05$). Both point and scatter stocking appear to be suitable methods for use in small rivers. The parr densities depend more on the other factors (e.g. habitat quality) than the stocking method, and the choice between methods could be based on the time and labour available.

JONES, R. A. 1966. Sea-run brown trout study. Federal Aid Project F-15-R-9, Final Report. Connecticut State Board of Fisheries and Game. Hartford, Connecticut. 32 p.

JONSSON, N., B. JONSSON, L. P. HANSEN and P. AASS. 1994. Effects of seawater-acclimatization and release sites on survival of hatchery-reared brown trout (*Salmo trutta*). Journal of Fish Biology 44(6) : 973-981.

To test whether seawater acclimatization of hatchery-reared anadromous and freshwater resident brown trout before release increased the survival of adults, smolts were retained 0, 2, 4, and 8 weeks in seawater before release. Total recapture rate increased for smolts retained 4 and 8 weeks in sea water before release relative to the controls. This trend was more pronounced for freshwater resident than for anadromous stocks. Offspring of anadromous fish stayed longer at sea than offspring of freshwater resident fish. Recapture rates in fresh water were higher for brown trout released in the river than in the fjord in the River Drammen area, but not in the River Imsa. In both cases, most fish were recaptured in the sea. Moving into the River Imsa (relative to other rivers) appeared higher for fish released at the mouth of the river (93%) than in the fjord (47%). Judging from the recapture rates, sea survival appeared to be the same whether released in the fjord or at the mouth of the river.

JONSSON, N., B. JONSSON, P. AASS and L. P. HANSEN. 1995. Brown trout (*Salmo trutta*) released to support recreational fishing in a Norwegian fjord. Journal of Fish Biology 46 : 70-84.

One-and two-year old hatchery reared juveniles of seven freshwater resident and anadromous populations of Scandinavian brown trout were released in the outer and inner part of the Oslofjord and in the River Akerselva, flowing through the city of Oslo. Recapture rates were highest (mean 20.3%) for river-released fish and lowest for those released in the outer (16.8%) and inner (12.1%) fjord. In general, recapture rate increased with fish size at release (r = 0.76). When released in freshwater, most of the recaptures were from fresh water and when released in the fjord, most recaptures were from the fjord. In general, freshwater resident stocks showed a higher degree of residency than anadromous stocks. However, mean migratory distance was longer for freshwater resident than anadromous fish. Trout moved longer distances at sea when released in the outer than in the inner fjord. Specific growth rate and size at recapture varied among release sites and stocks; they were highest for fish released in the outer fjord and lowest for river-released trout. There was no consistent difference in sea growth between freshwater resident and anadromous stocks. Estimated total yield was highest for fish released in the outer fjord, whereas there was no significant difference in yields between trout released in the river and the inner fjord Oslofjord.

JONSSONN, S., E. BRØNNØS and H. LUNDQUIST. 1999. Stocking of brown trout (*Salmo trutta*): Effects of acclimatization. Fisheries Management and Ecology 6(6) : 459-473.

One-year-old hatchery brown trout (*Salmo trutta*, n=16,520) from a local sea-run brood stock were marked and released (scatter-planted) into the River Laisälven in northern Sweden. Eight different groups were created using Alcian blue and Visible Implant Elastomer tags. Half the fish were kept in small enclosures in four stocking areas for 6 days before release. The other half were released just after transportation. To evaluate the effect of acclimatization on post-stocking performance, the areas were electro-fished 2 months later. During the electric fishing survey, a higher number of the acclimatized hatchery fish were recaptured than those released immediately. The growth rate of stocked fish differed significantly between stocking areas and fish held in enclosures grew more than those released directly. The rate of recapture of hatchery fish varied between stocking areas (6.4–17.4%). Movements of juveniles within and between the stocking areas were low, and only 3.6% of the recaptured fish were found in an area not originally stocked. These results showed that acclimatization of fish before release increases the number and size at recapture within a stocking area.

JORGENSEN, J. and S. BERG. 1991. Stocking experiments with 0+ and 1+ trout parr (*Salmo trutta*) of wild and hatchery origin: 2. Post-stocking movements. Journal of Fish Biology 39(2) : 171-180.

Wild and hatchery-reared 8-12 month old (5-8 cm) trout (*Salmo trutta*) were stocked into tributaries of River Gudena. Movements were examined by means of electrofishing. Overall dispersal and upstream movement were greater for wild trout than for domestic trout. Maximum distance of movement was 600 m upstream for both strains and 600 m downstream for wild trout, and 700 m for domestic trout. Upstream movement started within two months from stocking and continued for at least four months. Downstream movement during the first few days after stocking, was more pronounced for domestic trout than for wild trout.

JUTILA, E., A. AHVONEN and M. LAAMANEN. 1999. Influence of environmental factors on the density and biomass of stocked brown trout (*Salmo trutta*) parr in brooks affected by intensive forestry. Fisheries Management and Ecology 6(3) : 187-194.

The influence of environmental factors on the density and biomass of stocked brown trout (*Salmo trutta*) parr was studied in brooks subjected to intensive forestry in the Isojoki River basin, western Finland. Multivariate regression analysis showed that 69% of the variation in the population density of parr was determined by five variables: (1) mean water depth, (2) the abundance of pools, (3) stony bottom substrates with stones sized between 2 and < 10 cm in diameter, (4) undercut banks, and (5) the percentage of shading by trees. Correspondingly, 57% of the variation in the biomass of parr was determined by three variables: (1) mean water depth; (2) the abundance of pools; and (3) benthic vegetation. Dredging of the brooks and forest ditching had the most harmful consequences for the nursery habitats of brown trout parr. Measures for the rehabilitation of brown trout production in these brooks are discussed.

KAATRA, K. and O. SIMOLA. 1985. Water level regulation of Lake Inari: Impacts and compensation measures. p. 173-178. *In* J. S. Alabaster [ed.]. Habitat Modification and Freshwater Fisheries. Proceedings of a Symposium of the European Inland Fisheries Advisory Commission.

The ecological impact and compensation stocking, connected with the artificial water level fluctuations of Lake Inari (northern Finland) are reviewed. Stocking with Arctic char (*Salvelinus alpinus*) and lake char (*Salvelinus namaycush*) has been fairly successful, giving average yields per 1,000 tagged juveniles of 118 and 127 kg, respectively. Preliminary tagging results of stocking with brown trout (*Salmo trutta*) and land-locked salmon (*Salmo salar*) have been rather poor, perhaps because the newly stocked smolts migrate out of the lake. Better results may be sought by improving methods of breeding, increasing the size of the smolts, delaying the spring stocking and seeking better locations for releasing the fish.

KANE, D. 1996. Urban fishing moves forward. Virginia Wildlife 57(1) : 30-31.

A urban fishing program developed by the Virginia Department of Game and Inland Fisheries (VDGIF) and the City of Richmond calls for the release of 600 rainbow trout at Shields Lake, as well as stocking Byrd Park Lake with rainbow and brown trout from November through April. From May through October, both lakes will be stocked with catfish for a combined total of 6,000 fish released per year. This program also calls for stocking the Northwest River Park in Chesapeake, Dorey Park in Henrico County, and Locust State Park in Prince William County. But besides simply stocking lakes, this program has other aspects. Its main goal is to make fishing more accessible to large numbers of people. By stocking lakes, fishing is also presumably easier, which helps park rangers introduce school children to the excitement of fishing. Another part of this program is an agreement between VDGIF and Richmond City Recreation which provides fishing equipment for loan at Shields Lake for novice fisherman. This urban fishing program was first launched in December 1993 in Virginia's largest urban areas to encourage urban inhabitants to try the sport. To fish any of these lakes, a fresh water fishing license and trout license are required, although not for children under 16.

KELLEY, D. W. 1953. A study of the suitability of abandoned granite quarries near St. Cloud, Minnesota, for put-and-take fishing of brown and rainbow trout. Fisheries Investigational Report 141. Minnesota Department of Natural Resources. St. Paul, Minnesota. 9 p.

Abandoned granite quarries near St. Cloud, Minnesota, have long been stocked with trout to supply trout fishing. These quarries usually contain 50 to 75 feet of water and range in size from less than ¼ to more than 2 acres.

Investigations made in the summers of 1950 and 1951 showed thermoclines to be located usually at depths of 15 to 30 feet. Temperatures above the thermoclines in August, 1951, ranged from 66° to 70° F. On the basis of the amount of cooler and deeper water with sufficient oxygen for trout the quarries are of two types: (1) Those with a shallow layer of cool water (7 to 12 feet thick) that is suited to trout and (2) those with a thick layer of cool suitable water (18 to 23 feet thick). Water with a dissolved oxygen content less than 3.0 ppm was considered to be unsuitable for trout.

Past fishing history of these quarries suggested that a good return to the creel has been had from plantings of catchable-sized trout and that fingerling stocking has been of little value. To gather definite information on survival of stocked catchable-sized trout to the creel, Dodd Quarry was poisoned with rotenone in the fall of 1950 and stocked in the spring of 1951 with 337 brown trout weighing 4.5 to the pound. Subsequent check of anglers' catches showed a known return of 45% of the stocked fish and a probable total return of 60%.

Eight quarries were selected in 1953 to determine their capabilities for supplying put-and-take fishing of brown and rainbow trout. Four each of the two previously described types were used, two of which were planted with brown trout and two with rainbow trout. Stocking was done at the rate of about 75 pounds per acre and a total of 2,411 brown trout weighing 5.4 to the pound and 1,386 rainbow trout weighing 3.0 to the pound were planted in the eight quarries.

All planted trout were marked with a small monel-metal jaw tag attached to the opercle. This type of tagging later proved to be not too satisfactory since many trout were taken with torn opercles that had evidently lost their tags.

Despite tag loss, 33% of the tagged brown trout were taken by anglers and tags returned and 50% of the rainbow trout. No consistent difference of the percentage return of tags was noted from the two types of quarries.

An estimate of fishing pressure on the different quarries was obtained from 33 morning or evening counts of anglers on all quarries. To obtain an index of the comparative capability of each quarry to supply put-and-take fishing; the percentage return of tags for the season was divided by the total number and anglers counted on the quarry during the 33 counts.

By this index no consistent difference was found in the capabilities of the two types of quarries to supply put-and-take fishing. However, its use showed that the quarries were about three times more efficient in supplying put-and-take fishing for rainbow trout than they were for brown trout.

KELLY, W. H. 1965. A stocking formula for heavily fished trout streams. New York Fish and Game Journal 12(2) : 170-179.

A formula was developed to calculate the results of various rates of stocking large-sized trout in terms of return to the angler using creel census data concerning the catch and fishing pressure. The formula was field tested with marked (fin clipped) brown trout on Willowemoc Creek with promising results. It was also applied to data from Esopus Creek, Peeksill Hollow Creek, and the East Branch of the Delaware River to illustrate how management recommendations based on it might vary. An important feature is that it relates directly to the performance of hatchery trout during the first season after stocking. It also permits assessing the contributions of the wild population and of carryover fish from previous stocking. The value of a mathematical approach is considered to lie not so much in producing precise figures as in providing measurements of the dynamics of the existing fishery that may be used to guide management policy.

KELLY-QUINN, M. and J. J. BRACKEN. 1989$_a$. Survival of stocked hatchery-reared brown trout (*Salmo trutta*) fry in relation to the carrying capacity of a trout nursery stream. Aquaculture and Fisheries Management 20(2) : 211-226.

During the period June 1982-84, hatchery-reared brown trout (*Salmo trutta*) fry were stocked into stretches of the Owendoher, a trout nursery stream on the east coast of Ireland. These experiments were designed to examine the survival of stocked fry and to estimate the carrying capacity of the system. During the first year fry were stocked into sectors already supporting wild fish at densities normal for the system. In the following year, fry numbers were artificially reduced prior to stocking with the hatchery-reared fish. Mortality of the stocked fry was high after release with less than 33% of the fish surviving beyond the first 3 weeks. No stocked fish survived after October 1982. In the second year, however, 2-9% of the fish survived. The best survival rates were achieved where wild fry numbers were lowest. Regardless of the initial stocking density the various experiments yielded autumn fry densities (0.07-0.7 fish/m^2) similar to those at unstocked sites (0.1-0.62 fish/m^2). Stocking did not increase recruitment to the 1+ group and, again, 1+ densities (0.15-0.35 fish/m^2) similar to unstocked sites (9.07-0.39 fish/m^2) were obtained at the end of each year. These results suggest that spawning and recruitment in the Owendoher yield population densities approaching the maximum carrying capacity of the stream. The system appears to support a maximum summer fry density in the region of 1 fish/m^2 and a maximum autumn density of 0.7 fish/m^2.

KELLY-QUINN, M. and J. J. BRACKEN. 1989$_b$. A comparison of the diet of wild and stocked hatchery-reared brown trout (*Salmo trutta*) fry. Aquaculture and Fisheries Management 20(3) : 325-328.

This paper describes the results of dietary studies carried out during the course of a series of field experiments designed to examine the carrying capacity of the Owendoher. The diet of wild and stocked hatchery-reared brown trout fry was examined on three occasions (one week, one month and 2 months after stocking) between 7 July and 10 September 1982 and one week after a second stocking in July 1983. The stocked fish were Roscrea brown trout, a strain developed by the Central Fisheries Board in Ireland.

During the course of the investigation a total of 19 and 31 taxa were recorded in the stomachs of 86 wild and 84 stocked trout fry respectively. Within one week of release the stocked fish were consuming a similar range of organisms to the wild trout. In terms of weight, there was on average more food in the stomachs of stocked trout which was to be expected due to the larger size of these fish. Despite the fact that no empty stomachs were obtained there was greater variation in the amount of food present in the stomachs of stocked fish, particularly during the month of July. Trout fry stocked into the Owendoher Stream appeared to adjust quickly to natural feeding conditions.

KENNEDY, G. J. A. 1982. Stocking with brown trout. Report of the Symposium on Stock Enhancement in the Management of Freshwater Fisheries. European Inland Fisheries Advisory Commission Technical Paper 42 : 9-11.

This summarizes the papers presented in Session 2 of the symposium and discusses the preferred brown trout stocking techniques in Europe. Discussions centered on three main, interconnected aspects of trout stocking; the advantages of wild versus hatchery-reared fish, the apparent competition between brown trout and rainbow trout and migration of stocked trout.

It was generally agreed that the larger the trout at the time of stocking, the better its chances are for survival. Each increase of 3 cm in the mean length of stocked trout doubled the return of two-year old fish in Norway. Recommended minimum stocking sizes range from 18-25 cm and it was found that planting fish less than takeable size in polluted waters gave minimal success.

In Europe it was found that spring stocking gives much greater results than that which is conducted in autumn. The wild strains of stocked trout show a significantly greater level of success when stocked than do hatchery-reared strains of brown trout. It is speculated that the "tameness" of the hatchery fish along with their persistent silver shine makes them easier targets for predators.

The movement of stocked fish can greatly diminish the return to the fishery. Brown trout have been noted moving between 1 and 100 km downstream of their stocking site; for this reason stocking in lakes with outlets is not recommended.

KENNEDY, G. J. A., C. D. STRANGE and G. O. O'NEILL. 1982. Tagging studies of various age classes of brown trout (*Salmo trutta*). Fisheries Management 13(1) : 33-41.

Experiments carried out in hatchery ponds indicated that the survival and tag retention of tagged fish was significantly correlated to their length at tagging. Tag retention in small fish was found to be so low that tagging studies on these in the wild cannot be used to assess angler returns. It was also found that there were significant differences in tagging efficiency between different operators. Experiments were also carried out with tagged trout of four different ages, which were released into an angling lake. The best returns were obtained from spring-stocked 20 month old fish, of which 44.8% were recaptured. The results were also discussed in terms of the value of stocking different age classes of trout in relation to angling pressure and angling methods.

KENNEDY, G. J. A., C. D. STRANGE and G. O. O'NEILL. 1984. Survival of brown trout (*Salmo trutta*) stocked as summerlings and autumn fingerlings in two northern Ireland lakes. Fisheries Management 15 : 1-7.

The survival of 0+ brown trout, spray-marked with fluorescent pigment and stocked in two angling lakes as summerlings and autumn fingerlings, was assessed by netting exercises. About twice as many autumn fingerlings as summerlings survived the first winter after stocking and, in one lake, the percentage survival of the two groups was estimated at 31.0% and 15.2% respectively. Survival to age 2+ was estimated to be in the range of 5.7-9.7% for summerlings and from 15.1-16.6% for autumn fingerlings. The best survival for both groups was obtained in the most productive lake, where condition factors and growth rates were the highest. The results were assessed in economic terms, and the cost per age 2+ fish in each lake was more expensive from both summerling and autumn fingerling stocking than from direct introductions of fish-farm, two year old trout.

KERNEN, L. T. 1969. Footballs with fins! Wisconsin Conservation Bulletin 34(3) : 8-9.

Beginning in 1966, approximately 40,000 brown trout were stocked annually into the waters of Northern Lake Michigan. In 1967, the first spotting of spawning activity occurred. These fish appear to grow quickly and by mid July of 1968 many of these fish weighed six pounds. In comparison to the rainbow trout, the brown trout appear to remain in small areas once they reach the 2 pound mark. Newly stocked brown trout were captured up to half a mile from shore, in all depths of water, which may explain why anglers are catching few small trout. As they age the fish move towards the shallower waters inshore. The story is not all positive, however, the high level of aggression displayed in males caused a high incidence of disease when they rubbed together, fighting for spawning space.

KERR, S. J. 1983. A summary of 1983 upwelling incubation box projects within the Owen Sound district. Ontario Ministry of Natural Resources. Owen Sound, Ontario. 26 p. + appendices.

In a cooperative program between the Ministry of Natural Resources and three different sportsmen's associations, a total of six upwelling incubation box projects were undertaken during the fall of 1982 and spring of 1983. This involved the collection of 421,000 rainbow trout eggs and 53,104 brown trout eggs.

Hatching success ranged from 8.6-84.6% for rainbow trout and was estimated at 21.7% for the only brown trout rearing project.

A total of 188,343 rainbow and brown trout were released into the following waterbodies: Beatty Saugeen River, Colpay's Creek, Mitchell Creek, Oxender Creek, Pottawatomi River and Sydenham River.

This report outlines details on all aspects of the program, provides a summary of general problems encountered to date and offers some considerations for future projects.

KERR, S. J. 1984. Incubation box projects and fry plantings within the Owen Sound district. Ontario Ministry of Natural Resources. Owen Sound, Ontario. 22 p. + appendices.

Eight upwelling incubation box projects were carried out by local sportsmen's organizations under the Community Fisheries Involvement Program (CFIP) during the winter and spring of 1983-84.

In the only brown trout rearing project, hatching success was estimated at 52.5% and 21,148 fry were planted into Indian River, Pottawatomi River and Sydenham River.

Rainbow trout hatching success ranged from 25.2-85.7% in the seven remaining incubation box projects. In total, 271,059 rainbow trout fry were released in selected nursery streams during the spring of 1984.

Despite the variance in hatching success rates, reported hatching success had improved for every project which had been carried out in 1983.

This report summarizes operational details of 1983-84 upwelling projects, presents juvenile salmonid population assessment data for planted streams and provides a comparison with other projects carried out to date within southwestern Ontario.

KERR, S. J. and R. E. GRANT. 2000. Brown trout. p. 157-179. *In* Ecological Impacts of Fish Introductions: Evaluating the Risk. Fish and Wildlife Branch, Ontario Ministry of Natural Resources. Peterborough, Ontario. 473 p.

Brown trout and brook trout show a significant amount of overlap in their habitat requirements and dietary needs. As a consequence brown trout have been known to negatively impact brook trout populations when introduced into an occupied waterbody. Brown trout also prey upon brook trout. Brown trout have also been known to suppress Arctic charr populations and effect the growth rates of perch. Predation by brown trout can alter aquatic invertebrate communities. Brown trout can hybridize with Atlantic salmon and brook trout and therefore their introduction into a waterbody may cause the loss of native gene pools.

KERR, S. J., J. McNAUGHTON and R. GRANT. 1990. Brown trout stocking assessment investigation: Bolton Creek. Ontario Ministry of Natural Resources. Toronto, Ontario. 4 p.

No brown trout were captured during this investigation. Given the conditions noted it is highly doubtful brown trout could have survived in this portion of the creek. Based on our observations a number of recommendations are offered for future consideration.

Further brown trout stocking assessment – This investigation served to evaluate stocking success in the lower portion of Bolton Creek (Fallbrook to Chester's sideroad) as well as the Mitchell Creek sideroad bridge crossing site. It is recommended that the portion of creek between the Chester's and Mitchell sideroads also be walked and electrofished to determine the survival and distribution of trout from earlier plantings as well as evaluate the suitability of habitat to sustain brown trout.

Stream inventory/habitat assessment – Based on observations from this investgation the lower portion of the creek would not seem suitable to sustain brown trout. Further investigations are necessary to document the fisheries habitat in the upstream portion of the creek (above Mitchell sideroad) and evaluate its capacity to sustain alternate fish species such as brown trout. Due to the restricted access to much of Bolton Creek it is recommended that the creek actually be walked or perhaps flown by helicopter. In both instances various habitat parameters, such as water levels, beaver dams, pools and spring seepage areas, should be mapped and water temperatures should be recorded.

Habitat improvement – Physical characteristics of the creek and the relative abundance of small smallmouth bass would seem to make the lower portion of the creek best suited to the management of this species to provide a local fishery. To maximize production of smallmouth bass two basic types of habitat improvement will be required: (1) Low flow channel definition and (2) pool creation. Either type of project would be good candidates for either a CFIP project or an MNR sponsored habitat rehabilitation project.

KIRKLAND, L. and M. BOWLING. 1966. Preliminary observations on the establishment of a reservoir trout fishery. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 20 : 364-374.

A sport fishery for rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*) was created in the lower one-third of a 38,000-acre oligotrophic reservoir. Maximum temperatures of 70° F and a minimum of 3 ppm oxygen were evaluated as criteria for establishing this "two story" fishery. Stockings of 8-10 inch trout were made in the winter months and weight gains were up to threefold in a six month period. Food utilized by the trout was primarily the threadfin shad (*Drosoma petenense*). Movement of the trout did not exceed ten miles from the stocking locations and a majority was caught within five miles.

KLEIN, W. D. 1975. An evaluation of fingerling trout planting methods at Parvin Lake and West Lake, Colorado. Colorado Division of Wildlife. Denver, Colorado. 19 p.

There has been much controversy over the benefits of spot-planting versus scatter-planting. Two tests performed using brown trout fingerlings demonstrated a distinct advantage of scatter-planting over spot-planting in Lake Parvin. Fluorescent spray was used to determine relative survival of large plants of fingerling trout. This method can be implemented quickly and at a low cost.

The scattering of rainbow and brown trout fingerlings less than four inches in length is not recommended if conducted far from the shoreline. At this life-stage they prefer a littoral environment. Scatter plants of brown trout demonstrated higher survival rates than those of rainbow trout. This is likely explained by differential interactions with predator species and the behaviour of the trout stocked. Failure to disperse rapidly after planting could increase vulnerability to predation.

KOSA, J. 1999. Evaluation of rainbow and brown trout stockings in the Lake Cumberland tailwater. Fisheries Bulletin No. 102. Kentucky Department of Fish and Wildlife Resources. Frankfort, Kentucky. 42 p.

We evaluated the movement and exploitation of stocked brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) and the attitudes of anglers in a 38 mile section of the Lake Cumberland tailwater. Trout were batch-marked according to stocking location and time using multiple body locations of tags, tag types and tag combinations. Tag returns in a creel survey were used to assess dispersal and harvest patterns. Dispersal was similar for brown and rainbow trout. The longitudinal distribution of brown and rainbow trout catches were segregated based on stocking locations and this pattern was similar for brown and rainbow trout. In few cases did brown trout and rainbow trout move beyond the boundaries of their upper and lower stocking sites. Harvest was greatest among trout stocked in upstream locations. Exploitation rates were greatest for rainbow trout stocked in August and September. From March-November 1995, anglers fished an estimated 269,123 hours and angler effort peaked in July. The average trip length was 5.1 hours and the estimated number of trips was 52,431. Approximately 82% of the anglers interviewed were Kentucky residents and 21% were residents of the counties proximal to the river. Angling practices (release and harvest) differed dramatically between two strata within the study section. We recommend increasing the number of sites stocked and shifting stocking densities in consideration of spatial patterns of angler exploitation.

KOLARI, I. and E. IKONEN. 1989. Growth of sea trout (*Salmo trutta trutta*), size composition of catches and results of tagging experiments. International Council for the Exploration of the Sea Council Meeting Collected Papers, Copenhagen, Denmark. 13 p.

During the 1980s, one million sea trout (*Salmo trutta*) smolts have been released yearly off the Finnish coast. In order to obtain information on the results of the stocking, tagging experiments have been done. In 1980-1986, a total of 74,438 fish were tagged. Data on sea trout caught with different gears were collected by fishermen in 1987. Stocking gave the best results in the Archipelago Sea and the worst in the Bothnian Bay. The poor stocking results in the Bothnian Bay are partly due to fishing of sea trout too soon after release.

KRIEG, F and R. GUYOMARD. 1985. Population genetics of French brown trout (*Salmo trutta*): Large geographical differentiation of wild populations and high similarity of domesticated stocks. Génétics, Sélection, Evolution 17 : 225-242.

KRUEGER, C. C., J. E. MARSDEN and B. MAY. 1986. Genetic comparison of New York hatchery strains of brown trout based on allozyme variation. New York Fish and Game Journal 33(1) : 16-27.

Allozyme variation was compared within and among three hatchery stocks of brown trout to determine genetic differences among strains. Of the 71 total loci, 17 were polymorphic. The average estimated heterozygosity was 0.046 for the Rome Lab strain, 0.040 for the Randolph strain and 0.042 for the Catskill strain. Heterogeneity tests over all loci and by locus indicated significant genetic differences among strains. Cluster analysis of relative genetic distance coefficients grouped the Rome Lab and Randolph strains together. A similar analysis was conducted with combined data from this study and an unpublished study at Pennsylvania State University. The latter included a sample from an earlier year class of the Randolph strain and a sample from the hatchery at Hackettstown, New Jersey, the presumed progenitor of the Catskill strain. Cluster analysis grouped the two Randolph year classes together and these were then grouped with the Rome Lab strain. The Catskill and Hackettstown strains were no more genetically similar to each other than to the Rome Lab-Randolph group. These results indicated that all three New York hatchery stocks of brown trout were genetically distinct from each other, which was surprising since the Randolph strain was established in 1978 by a transfer of fertilized eggs from the Rome Lab strain.

KRUEGER, C. C. and B. MAY. 1987. Stock identification of naturalized brown trout in Lake Superior tributaries: Differentiation based on allozyme data. Transactions of the American Fisheries Society 116(6) : 785-794.

Eight collections of brown trout (*Salmo trutta*) from four Lake Superior tributary systems in Wisconsin (the species' principal range in the Lake Superior drainage) were analyzed electrophoretically for enzyme expression at 15 polymorphic loci. Collections included site-specific samples from the Brule River, as well as anadromous and resident fish from the Brule and Sioux Rivers. Significant differences occurred among the eight samples at 6 and 12 possible locus comparisons ($P<0.01$). Hierarchial analysis indicated that significant differences also occurred among the four drainages and among samples within drainages. Average genetic fixation values F_{st} indicated that the genetic variation observed among the four drainages represented approximately 1.9% of the total variation and was similar to the variation observed among samples within the Brule and Sioux drainages (1.6%). The average sample of brown trout contained about 96.5% of the genetic variation observed. Comparisons between anadromous and resident fish indicated significant genetic differences in the Brule River ($P<0.01$) and nearly significant ones in the Sioux River ($P<0.07$). Thus, brown trout from southwestern Lake Superior drainages appear to have a population structure organized by drainage system and by life history. Their level of stock differentiation was much less that that observed in native populations from Northern Ireland, and probably reflects the recent (1900s) introduction of brown trout to the Lake Superior watershed. Similarly, differentiation among New York State hatchery stocks was 2.2 times greater than that observed among wild Lake Superior populations. Genetic differences among Lake Superior brown trout may indicate a relatively rapid rate of population differentiation since introduction, or the partial preservation of the original genetic identities of the different European sources that were stocked into the basin. Management actions such as stocking, regulations, and assessment should be chosen that will preserve the stock structure of brown trout in Lake Superior.

KRUEGER, C. C. and B. MAY. 1991. Ecological and genetic effects of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48 (Supplement 1) : 66-77.

Stocking of non-native Salmoninae into North American waters began around 1870. Brown trout (*Salmo trutta*) from Europe established populations across North America and is the only successful intercontinental introduction. The success of the brown trout has come at the expense of other species. Over the past one hundred years, brook trout have been disappearing from their native North American streams because of their inability to compete with the introduced brown trout. Both species occupy similar habitats and have an extensive diet overlap. Studies have shown that brown trout dominate preferred brook trout resting positions in streams and there is also significant overlap in their preferred winter habitat. Changing environmental factors such as stream warming and deforestation may have facilitated the colonization of brown trout in brook trout territory.

Brown trout can also impact upon non-salmonid species. Through experimentation it was found that small trout have a lesser impact on prey species than large trout. Through the experimentation period the most abundant prey species (the torrent sucker) decreased in the stream section stocked with large brown trout. Using predatory mechanisms introduced brown trout can alter the fish assemblages in stocked waters.

KUEHN, J. H. and R. E. SCHUMACHER. 1957. Preliminary report on a two-year census on four southeastern Minnesota streams. Investigational Report No. 186. Division of Game and Fish, Bureau of Research and Planning, Minnesota Department of Conservation. St. Paul, Minnesota. 41 p.

A creel census was conducted on four southeastern Minnesota trout streams over a two-year period. Electrofishing population estimates were made before and after each season. A two-way fish weir was installed at the lower end of one stream. Stocked trout made up 51% and 79% of the catch in each of the two respective years. Returns varied from 29.7% to 72.8% among the various streams and brown and rainbow trout which were stocked in equal numbers contributed almost equally to the catch. A natural mortality of 40% was found for brook, brown, and rainbow trout stocked. The streams having the best number of trout available per angling hour provided the highest rate of catch. Downstream movement resulted in a loss to the stream of 5.3% of the stocked trout and consisted mostly of rainbow and brook trout. Sixty-seven percent of fall-stocked brown trout were lost before the angling season began.

L'ABEE-LUND, J. H. and A. LANGELAND. 1995. Recaptures and resource use of native and non-native brown trout (*Salmo trutta*) released in a Norwegian lake. Fisheries Management and Ecology 2(2) : 135-145.

Rate of recapture (gill netting), habitat use, and diet of three strains of stocked brown trout (*Salmo trutta*) were compared with resident brown trout in a Norwegian lake. The strains originated from an alpine lake, from a boreal lake, and from the native brown trout population in the lake. Overall recapture rate was 5-8% for all strains. The low recapture rate could be due to the relatively small size at stocking; mean fish length varied between 13.1 and 14.5 cm with strain and stocking method. Two years after release, the frequency of the different strains decreased from about 12% in the first year to stabilize at about 1%. The alpine strain showed the highest overall recapture rate, whereas the native strain was recaptured at an intermediate rate. The overall recapture rate of scatter-planted brown trout was higher than that of spot-planted brown trout. Immediately after being stocked, introduced fish ate less and had a less varied diet than resident trout; however, stocked fish adopted a natural diet within the first summer. The distribution of trout between the pelagic and the upper epibenthic habitat was similar for both the resident and the stocked brown trout. Results indicate that the habitat use of stocked brown trout is adaptive and becomes similar to that of indigenous fish.

L'ABEE-LUND, J. H. and H. SÆGROV. 1991. Resource use, growth and effects of stocking in alpine brown trout (*Salmo trutta*). Aquaculture and Fisheries Management 22 : 519-526.

Wild and stocked brown trout (*Salmo trutta*) were sampled in the alpine Norwegian Lake Bjornesfjorden by standard net gangs and commercial fishery. Stocked fish comprised about 30% of the total stock. There was no significant difference in spatial distribution and diet between native and stocked fish. Both groups used the littoral zone and *Gammarus lacustris* and *Lepidurus arcticus* were the main food items. Stocked brown trout reached a specific length one year younger than corresponding wild fish. Therefore stocked brown trout entered the commercial catch one year younger than the native fish.

L'ABEE-LUND, J. H. and H. SÆGROV. 1992. Piscivory by brown trout (*Salmo trutta*) and Arctic charr (*Salvelinus alpinus*) in Norwegian lakes. Journal of Fish Biology 41 : 91-101.

Size and frequency of occurrence of prey of brown trout (*Salmo trutta*) and Arctic charr (*Salvelinus alpinus*) were recorded in 13 Norwegian lakes during 1973-1990. One of these lakes was stocked with brown trout due to low natural reproduction. Piscivores usually comprised less than 5% of the total population. Arctic charr were less piscivorous than brown trout. Trout and charr became piscivorous at 13 and 16 cm in length, respectively. These size thresholds were similar to those of other facultative piscivorous freshwater fish species. When present, three-spined sticklebacks (*Gasterosteus aculeatus*) were preferred by all length groups of piscivorous brown trout and Arctic charr. Length of prey increased with increasing predator length for trout and charr, respectively. Yearlings of charr were not recorded as prey. The Tunhovdfjord strain of brown trout stocked in Lake 11 exhibited a substantial piscivorous diet by consuming sticklebacks.

L'ABEE-LUND, J. H. H. SÆGROV and H. LURA. 1992. Resource partitioning and spatial segregation in native and stocked brown trout (*Salmo trutta*) and Arctic charr (*Salvelinus alpinus*) in a hydroelectric reservoir. Aquaculture and Fisheries Management 23 : 623-632.

Habitat use, food and spatial segregation in native and stocked brown trout (*Salmo trutta*) and Arctic charr (*Salvelinus alpinus*) were studied during summer 1989 and 1990 in the hydroelectric reservoir Lake Tunhovdfjorden. There was no difference in habitat use and feeding habits between wild and stocked brown trout. In epibenthic areas brown trout lived chiefly down to 2 Secchi disc units whereas Arctic charr were most abundant between 1 and 4 Secchi disc units. In pelagic areas the catches were low for both species and they were chiefly confined to surface waters down to 1 Secchi disc unit. The food segregation between brown trout and Arctic charr was almost complete. Both pelagic and epibenthic Arctic charr fed mainly on cladocerans (*Bosmina longispina* and *Daphnia galeata*) whereas surface insects of terrestrial origin and Arctic charr were the dominant food items for brown trout. Pelagic Arctic charr were significantly older, larger and more homogeneous in size than epibenthic charr. During calm weather schools of Arctic charr were observed cruising with the dorsal fin above the surface.

LACHNER, E. A. and E. C. RANEY. 1941. Autumn food of recently planted young brown trout in small streams of central New York. Transactions of the American Fisheries Society 71 : 106-111.

Populations of young brown trout (*Salmo trutta*, 66-111 mm in total length) were sampled during late August to November at known intervals after they had been planted in two streams. The stomach contents of 75 were analyzed. Two days after planting, 16 out of 26 stomachs contained some food; 82% by volume was of aquatic origin. Only insects were eaten and of these Ephermeroptera and Diptera were most important. After 16 days each of 20 stomachs contained food. Aquatic food still dominated (86%), and a large part (93%) were insects. Epheremoptera and Diptera were still most important although beetles (Coleoptera) were present to the extent of 21% by volume. Earthworms, Arachnia, and isopods also were eaten. After 42 days 10 trout were obtained. Aquatic organisms still made up a large part (79%) of the stomach contents. Insects still predominated (86%) and while mayflies (Epheremoptera) were still most important, Diptera, Orthoptera, Hemiptera and Plecoptera were well represented. The remains of a fish was found in one stomach.

In another stream with a slightly different bottom fauna, 20 out of 22 stomachs contained food three days after the fish had been planted. Most of the food (95%) was aquatic in origin, and 95% were insects of which Diptera and Trichoptera were most important.

LARGIADER, C. R. and A. SCHOLL. 1995. Effects of fish stocking on the genetic diversity of brown trout populations of the Adriatic and Danubian drainages in Switzerland. Journal of Fish Biology 47 (Supplement A) : 209-225.

This study focuses on genetic variation of brown trout (*Salmo trutta*) populations of the Adriatic and Danubian drainages in Switzerland. The allozyme and other protein loci data show a major replacement of native stocks from the Adriatic drainages by introduced hatchery trout of Atlantic basin origin. In most samples, diagnostic alleles for the Adriatic form of *Salmo trutta fario* and for the marbled trout (*Salmo trutta marmoratus*) are found at very low frequencies (f<0.15). Taking into account previous genetic studies on brown trout of this basin, the Danubian samples are not heavily contaminated with foreign alleles. The results are consistent with records of local stocking activities which account in part for the high introgression rates of Atlantic alleles into local populations of the Adriatic drainages. In addition, introgression is enhanced by a decrease of natural reproduction which is caused by a deterioration of trout habitats through human activities. Furthermore, a third mechanism is proposed that may contribute to the high introgression rates observed: if Atlantic trout are introduced, the reproductive barriers between the two native forms, marbled trout and Adriatic *fario* respectively, break down. Atlantic trout apparently hybridize with both native forms and generate gene flow between them. In some parts of the Adriatic drainages in Switzerland, the patterns of introgression and hybridization are further complicated by the introduction of trout from the Danubian system. Alleles of the marbled trout are also found in the samples of the Danubian drainage system. These are due to stocking activities across the watershed.

LARGIADER, C. R. and A. SCHOLL. 1996. Genetic introgression between native and introduced brown trout (*Salmo trutta*) populations in the Rhone River Basin. Molecular Ecology 5(3) : 417-426.

In the Doubs River (Rhone drainage) two distinct brown trout (*Salmo trutta*) phenotypes are observed. One phenotype is locally called Doubs trout and is characterized by four black stripes on the sides, similar to perch (*Perca fluviatilis*) and the other is the common phenotype of the fluviatile ecotype of brown trout (*Salmo trutta fario*). Protein data for three samples from the Doubs show that the Doubs trout belongs to the Mediterranean population group of brown trout, whereas the *fario* phenotype originates from stocking with hatchery strains of Atlantic basin origin. The two forms, however, do not hybridize freely. This is indicated by considerable gametic phase disequilibrium between alleles of hatchery and Doubs trout at one sampling site, and by lack of intermediate genotypes and phenotypes at another sampling site. The introgression patterns observed at the two sites suggest that differences in local habitat conditions can affect the degree of hybridization and introgression.

LARGIADER, C. R., A. SCHOLL and R. GUYOMARD. 1996. The role of natural and artificial propagation on the genetic diversity of brown trout (*Salmo trutta*) of the Upper Rhone Drainage. p. 181-197. *In* Conservation of Endangered Freshwater Fish in Europe. Birkhaeuser Verlag. Basel, Switzerland.

Previous protein studies found diagnostic alleles for Atlantic and Mediterranean brown trout (*Salmo trutta*) populations. Lake Geneva and the upper Rhone belong to the Mediterranean drainage system. Therefore, we would expect that autochthonous brown trout populations from this area would show the Mediterranean alleles. In most cases, however, we found Atlantic alleles in high frequencies ($f > 0.8$). Intense stocking has occurred in this area with hatchery strains originating from the Atlantic drainage system. Thus, the obvious interpretation of our data is that the presence of Atlantic alleles results from stocking. However if we take into account information other than present geography we may propose alternative hypotheses that would explain the Atlantic alleles, e.g., an immigration of Atlantic trout from the Rhine system after the last Ice Age. Several post-glacial colonization scenarios for Lake Geneva and its tributaries are discussed and compared to our protein data. The implications of our findings relative to conservation of the genetic diversity of brown trout in this region are also discussed.

LARSEN, K. 1959. The effect of the liberation of sea-trout fry in the Gudenå area, as shown by the trout catch in the Lower River and the Randers Fjord. Conseil International pour L'Exploration de la Mer, Rapport et Proc.-Verbale 148 : 26-28.

LARSEN, K. 1972. New trends in planting trout in lowland streams: The result of some controlled Danish liberations. Aquaculture 1: 137-171.

Planless liberations of brown trout in Danish streams prior to 1930 did not result in any convincing improvement of the stocks. Planned liberations of tiny fry, distributed as widely as possible to streams which complied with the requirements of this size of fish, had some but still too little effect. Modern liberations of fry as well as older fish, as to size and number leveled to the natural conditions of the streams and to stock present before, have however, shown satisfactory results. Examples based on controlled liberation experiments are given.

In the early 1960s, it was believed that trout liberation, aimed at utilizing the productivity of all small and medium sized streams within a water system, should be undertaken if a positive result could be achieved. The planting material should be spread as widely as possible over all the water system in order to utilize its full production capacity. The size of the liberated fish should be adjusted to the volume of the streams especially the depth. Thus, fry should be planted at depths up to 10 cm, half-yearlings at depths between 10 and 15 cm, 1½ yearlings at depths between 15 and 25 cm and two year old fish at depths beyond that. Depth here is defined as normal summer depth. The number of planted fish should be adjusted according to a combination between the quality of the biotope as a trout water (not least including the amount of shelter) and the already existing population of young trout as demonstrated by a population analysis.

LARSSON, P.-O., N. G. STEFFNER, H.-O. LARSSON and C. ERICKSSON. 1979. Review of Swedish sea trout (*Salmo trutta*) stocks based on results of tagging experiments. Salmon Research Institute Report No. 2. Alvkarleby, Sweden. 31 p.

The results of tagging experiments with natural smolt and parr and hatchery-reared smolt sized parr (mainly 2 year olds) of trout (*Salmo trutta*) are reviewed with regard to growth, survival and possible fitness for stocking purposes. All experiments by the Swedish Salmon Research Institute and some by the Fishery Board are included, and were all performed with Carlin tags. There are few pure stocks of sea trout, as in most rivers a variety of stocks have been introduced. Climatological differences are believed to cause the general trend in the results, both growth and survival increase from north to south. Three varieties of sea trout can be distinguished: one stationary type in all the northern and some of the southern Baltic rivers, one wide migration fast growing form in some southern Baltic rivers and one west coast type with poor growth and return rates. Releases at the coast even far from home rivers, give in many cases good results, up to

1,000 kg/1,000 released fish in the Main Basin. Rivers Dalalven, Eman, Morrum, Gullspang and Weichsel (Poland) stocks and crosses between them are recommended for further stockings.

LEMMIEN, W. A., P. I. TACK and W. F. MOROFSKY. 1957. Results from planting brown trout and rainbow trout in August Creek, Kalamazoo County, Michigan. Quarterly Bulletin of Michigan Agricultural Experiment Station 40 : 242-249.

LINLØKKEN, A., T. TAUGBØL, T. NAESS, O. T. IGLAND and Å. HUSEBØ. 1999. A comparison of genetic variability in artificial and natural populations of brown trout in a regulated river system. Regulated Rivers: Research and Management 15(1-3) : 159-168.

Brown trout were sampled from tributaries of Glomma, the largest river system in Norway. Brown trout were formerly known to migrate long distances, but several dams and river regulations have made migration difficult, as fishways constructed at the dams are not efficient. To compensate for the resultant reduction in brown trout, the river system has been stocked with hatchery fish reared from native brown trout.

Genetic analysis by enzyme electrophoresis was conducted to monitor possible genetic effects on native fish. Brown trout were obtained from a fishway at Løpet in the South Rena River, and from a section at Deset, 16 km upstream of the fishway. One sample was taken from a cohort of first generation hatchery fish based on only six spawning fish collected in the fishway, and one sample was taken from the second hatchery generation, bred from a mixture of two cohorts of first generation hatchery fish. The pooled brood stock of these two first generation cohorts numbered five females and five males. Eight samples were taken from second-, third-, and fourth-order streams containing populations differing in size and degree of isolation.

Tissue samples taken from eye, liver and muscle were analyzed using starch gel electrophoresis for protein polymorphism to determine genetic population structures. Allele frequencies, heterozygosity and polymorphism were compared. The fraction of heterozygosity ranged from 3.3 to 13.5% in the wild populations, and the lowest fraction was found in the most isolated population. Heterozygosity was 8.0% in the first generation of hatchery-reared fish and 7.3% in the second generation. The number of detected polymorphic loci ranged from one to seven, with a mean of 4.5, in wild populations, but was three in the first generation and four in the second generation of hatchery fish. Polymorphism seemed to be lost at three loci in the first generation, but one locus was restored in the second generation, probably due to breeding with another hatchery cohort.

LOEB, H. A. 1964. Jaw marking trout with injection dyes. New York Fish and Game Journal 11(2) :159-160.

Ten water soluble dyes were injected to the lower jaws of yearling brown trout. Fast Pink BL and Solantine Turquoise G lasted the longest, for a period of over 9 months. The marks were produced using a No. 26 hypodermic needle. The needle is inserted into the fish so that it runs along the length of the jaw from the dentary bone to the articular bone. As the needle is withdrawn the dye is slowly injected into the tunnel created by the needle, leaving a coloured line.

LOEB, H. A. 1968. Duration of jaw marks in growing fingerling trout. New York Fish and Game Journal 15(2) : 193-194.

A total of 46 brown trout averaging 3.4 inches in length were injected in both jaws with a 6.1% solution of dye. This was accomplished using a 0.5-inch #27 needle. Three months following the injection the average weight gain was 150%. At 7 months, the mean weight gain was 1,040% and most marks were no longer visible. It appears that large trout lose their marks after less relative gain in weight than do small trout.

Jaw injection marking is practical on trout as small as 2.5 inches in length, yet cheek marks can be made on fish as small as 1.5 inches. However, it has been found that cheek marking causes some mortality.

LORZ, H. W. 1974. Ecology and management of brown trout in Little Deschutes River. Fisheries Research Report No. 8. Oregon Wildlife Commission. Portland, Oregon. 49 p.

LOUDER, D. E. 1969. Principles of trout management. Wildlife in North Carolina 1969 (September) : 14-16.

The trout streams in North Carolina are valuable resources, however, increasing fishing pressure is being placed on smaller areas of water. This is occurring because trout waters are being lost to private lands, no longer allowing an equal amount of fishing access and instead concentrating the fishing in areas which are not used to high pressure fishing. At present, North Carolina is stocking 603,600 catchable trout, 153,900 of which are brown trout. These fish are being stocked into public fishing areas (253 streams) and wildlife management areas. Fingerlings are being de-emphasized since they are significantly more expensive to stock than catchable fish. Hatcheries may not be contributing enough to the angler's creel. At last count only one-fifth of the trout caught were of hatchery origin. It appears that protecting the wild trout is essential to preserving the trout fisheries.

LUCAS, M. C. 1993. Food interrelationships between brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in a small put-and-take stillwater fishery. Aquaculture and Fisheries Management 24 : 355-364.

The food of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in a small stillwater put-and-take fishery in Surrey, England, was examined by stomach content analysis of fish caught by angling between the months of April and September, 1985. Overall, brown and rainbow trout tended to utilize different food sources. Mann-Whitney U-tests showed most major food items to be eaten in significantly different amounts, the most important exceptions being chironomid pupae and adult Diptera. In all months except April, rainbow trout utilized mainly midwater food, particularly Cladocera. Brown trout fed mainly on benthic food organisms and fish. Spearman rank correlations showed diets to be dissimilar during this period with significant negative correlations in May and August. These results indicate an absence of interspecific competition for food and imply spatial separation of brown and rainbow trout. In April, both brown and rainbow trout fed extensively on the temporary bottom fauna, mainly trichopteran and megalopteran larvae, and diets were significantly positively correlated.

LUISI, M. P. and P. W. BETTOLI. 2000. An evaluation of the trout fishery on the Hiwassee River below Apalachia Dam. Presented at the 2000 midyear Conference of the Southern Division of the American Fisheries Society, Savannah, Georgia. (Abstract only)

The Tennessee Wildlife Resource Agency annually stocks the Hiwassee River below Apalachia Dam with about 100,000 catchable (> 200 mm TL) rainbow trout (*Oncorhynchus mykiss*) and 18,000 catchable brown trout (*Salmo trutta*). However, because of difficulty in sampling this tailwater, the performance and fate of these salmonids was unknown. The objectives of this study were to evaluate the growth, survival, and condition of stocked trout. All of the brown trout and four cohorts of rainbow trout were marked using uncoded wire microtags. Monthly samples were taken from February through December 1999 using a whitewater electrofishing raft and a jet powered electrofishing boat. With the exception of the January cohort, growth and survival were poor for all rainbow trout. Brown trout growth on the Hiwassee River was slow, when compared to the other Tennessee tailwaters. A survey to estimate the populations size and standing crop of trout was conducted in February 1999 and will be repeated in January 2000. The 1999 survey revealed low numbers of holdover trout (59/ha) and biomass (20 kg/ha) when compared to other tailwater systems.

LUTON, J. R. 1985. The first introductions of brown trout (*Salmo trutta*) in the United States. Fisheries 10(1) : 10-13.

It is believed that Fred Mather brought the first brown trout to America in the early 1870s. Following this there were numerous introductions made by other early fish-culturists and various attempts (usually successful) to raise the fish in hatcheries. Mather's brown trout resided at Cold Spring Harbor, New York, where they were typically shown to visitors. The practice of netting the fish from their ponds to present to visitors, traumatized the fish to such an extent that the fish would later jump out of the ponds on their own. Less than 1.3% of the brown trout from this hatched batch of 4,000 survived to be stocked.

MacCRIMMON, H. R. and T. L. MARSHALL. 1968. World distribution of brown trout (*Salmo trutta*). Journal of the Fisheries Research Board of Canada 25(12) : 2527-2548.

During the past century, the Eurasian and North African range of the brown trout (*Salmo trutta*) has been extended to include discontinuous populations on all continents except Antarctica. Primary factors affecting the establishment of naturalized populations are water temperature, precipitation, and suitable spawning grounds. Any future major expansion in the world distribution of the brown trout, with the possible exception of Asia, is unlikely.

MACHORDOM, A., J. L. GARCIA-MARIN, N. SANZ, A. ALMODCVAR and C. PLA. 1999. Allozyme diversity in brown trout (*Salmo trutta*) from Central Spain: Genetic consequence of restocking. Freshwater Biology 41(4) : 707-718.

The brown trout (*Salmo trutta*) represents one of the main freshwater resources in Spain, but habitat alterations and overharvesting have contributed to the decline or disappearance of numerous natural populations. In addition, reinforcement programs of wild populations based on releases of hatchery-reared fish of exogenous origin compromise the conservation of remnant native trout resources.

We present allozymic data from Central Spain trout populations including stocked and unstocked populations. Although the levels of genetic variation observed were low and affected by hatchery releases ($p = 18.23\%$, $H_o = 3.39\%$), they were within the range observed in other European areas.

The effective introduction of hatchery-reared fish is genetically homogenizing the populations in the studied area and disturbing the ancestral pattern of genetic variation that distinguishes the Tajo and Duero basins. Within the eight natural populations analyzed, seven had alleles assigned to the foreign trout. The introgression in these populations, following the LDH-5*90 allele frequency, ranged between 2% and 29.4%, but those values are not in concordance with the respective stocking effort undertaken in each population. Moreover, the release of hatchery-reared fish does not solve the problems related to the reduced size of wild populations and their recruitment instability.

MacKAY, H. H. Undated. Fish management in Ontario with special reference to the role of hatcheries. Ontario Department of Lands and Forests. Toronto, Ontario. 6 p.

Precautions are taken in the planting of fish into new waters owing to the possible detrimental effects that may result. As of now the introduction of brown trout into waters in northern Ontario is not recommended. The brown trout empty the food supply and occupy the breeding grounds so that brook trout have a difficult time competing with them. In contrast, there are arguments being made for the introduction of brown trout into brook trout waters: (1) The brown trout is said to be more tolerant of low, warm waters and can withstand greater seasonal fluctuations than the brook trout thus making them more suitable for stocking in certain areas; and (2) an increase in fishing intensity requires a fish which is more difficult to capture than the brook trout.

MacKAY, H. H. 1957. The brown trout. Sylva 13(2) : 25-31.

Although the brown trout is native to western Europe and the British Isles it has been propagated artificially and stocked into waters in New Zealand, Africa and America. The brown trout first arrived in the United States in 1883, and Newfoundland in 1884; it did not reach Ontario (officially) until 1913. Currently, in Ontario, the Normandale Ponds are used to hold brown trout broodstock which supply trout that can be reared to the yearling stage in various Ontario hatcheries.

Widespread plantings have been made in Brant, Bruce, Carleton, Durham, Elgin, Grey, Haldimand, Halton, Manitoulin, Norfolk, Peterborough, Simcoe, Waterloo and Wellington counties. The stocking of brown trout has displaced some brook trout populations. Second plantings of young fish are impractical since the brown trout will prey on their own young, as well as those of other species. When water quality is poor brown trout can only be maintained through continuous stocking.

MAINE FISHERIES RESEARCH AND MANAGEMENT SECTION. 2000. Guidelines to fish stocking in Maine. Maine Department of Inland Fisheries and Wildlife. Bangor, Maine.

Brown trout are not stocked where there exists important wild brook trout populations or runs of Atlantic salmon. They are, however, planted alongside brook trout in suitable waters. Brown trout provide fishing opportunity in the summer and early fall after the brook trout have disappeared. Most stocking which is done in the state occurs in the southern and central portion.

Lakes and ponds are typically stocked with brown trout 12 inches long, fall yearlings, while streams are stocked with spring yearlings, measuring approximately 9 inches.

When stocking brown trout the amount of available summertime habitat is important in determining the stocking rate. Angler use is also key in deciding what numbers of fish to stock. Presence of predators, competing species and food abundance should also be considered. In lakes and ponds brown trout are generally stocked at a rate of one fall fingerling per acre, while rates for stream stocking vary.

Fall yearlings are usually stocked along the shoreline of the recipient lake, while streams are scatter-planted near road crossings and access points.

MAISSE, G., J. P. PORCHER, A. NIHOUARN and B. CHEVASSUS. 1983. Comparison of performances in hatchery and in streams of an interstrain hybrid (wild male x domestic female) of brown trout (*Salmo trutta*) and of the maternal strain. Bulletin Français de la Pêche et de la Pisciculture 291 : 167-181.

Performances, in hatchery and then in streams, of an interstrain hybrid (wild male domestic of brown trout x female wild brown trout (*Salmo trutta*)) are compared with those of the maternal strain in the same conditions. It is shown that during the rearing period the hybrid grows less than the maternal strain and is more sensitive to costia (the flagellate which causes costiasis – a fatal fish disease) in relation with less performances during yolk sac resorption and the start of feeding. During the stream period the implantation level for each origin depends on the habitat. The use of such a hybridization for stocking wild waters is discussed in terms of several planting strategies.

MALHIOT, M. 1999. Assessment of brown trout stocking in the Nine Mile River, Ontario. Unpublished data. Ontario Ministry of Natural Resources. Clinton, Ontario. 2 p.

Brown trout were planted in the Nine Mile River annually, with the exception of 1992, between 1987 and 1994. Stocking rates ranged from 3,000 (1991) to 9,000 (1994) fish per year. Over the seven year period, a total of 35,900 brown trout were stocked. All trout were differentially marked by fin clip. Returns of clipped brown trout to the Port Albert fishway were monitored in 1988, 1993 and 1994. Numbers of fin clipped trout observed at the fishway was 16 fish in 1988, 80 fish in 1993 and 83 fish in 1984. Over the three years, only 179 trout, representing 0.5% of the total number stocked, were recorded.

MANITOBA DEPARTMENT OF NATURAL RESOURCES. 1991. An evaluation and revision of Manitoba's fish stocking strategy and implementation plan. Fisheries Branch, Manitoba Department of Natural Resources. Winnipeg, Manitoba. 27 p.

Excess brown trout are often produced at the Provincial hatchery and these surpluses are not typically costly if they can be stocked in early spring. If fish can be stocked in the fall as fingerlings then costs can be minimized as it is less expensive to transport the fish greater distances than to feed them for longer periods. Those regions in the eastern and southeastern portion of the province are cheaper to stock and are ideal areas for excess fish.

MANSELL, W. D. 1966. Brown trout in southwestern Ontario. Ontario Fish and Wildlife Review 5(2) : 3-8.

Two strains of the brown trout (the "German" and the "Loch Leven" brown trout) were introduced to eastern North America around 1883. The first recorded planting of a brown trout in Ontario was in 1913 with the release of fingerlings in the counties of Wellington, Simcoe, Norfolk and Perth. Both strains are able to withstand a wide range of temperatures and are very competitive thus, the majority of the introductions were successful. Unfortunately, the success of the brown trout often came at the expense of the brook trout. It is recommended that the culture of brown trout be discontinued, as they do not contribute in large amounts to the fishery. They are a wary species and thus difficult to capture.

MARCINKO, M. T., R. D. LORSON, and R. A. SNYDER. 1990. Changes in wild brown trout standing stocks after termination of stocking. p. 83-88. *In* J. C. Borawa [ed.]. Brown Trout Workshop: Biology and Management. American Fisheries Society, Southern Division. Asheville, North Carolina.

MARCONATO, E., S. SALVIATI and G. MAIO. 1990. Population dynamics of brown trout (*Salmo trutta*) in a nursery stream. Rivista di Idrobiologia 29(1) : 343-352.

An experiment was carried out in a small water body of the Provincia of Padua (north-east of Italy). The evolution of the initial *Salmo trutta* stock was monitored by quantitative samples on selected sites. The results show a low rate of fry dispersion from the release point, low growth and high mortality rates. The data collected are useful to improve the management of these trout populations.

MARSHALL, S. A. and B. W. MENZEL. 1984. Recovery, growth and habitat utilization of spring-stocked fingerling brown trout (*Salmo trutta*) in six northeast Iowa streams. *In* Proceedings of the 64th Annual Conference of the Western Association of Fish and Wildlife Agencies, Victoria, British Columbia.

The relative merits were investigated of two methods of stocking in marginal trout waters: spot stocking where a large number of fish are introduced at one site; and scatter stocking where fish are introduced in smaller numbers over a length of stream. This study also provided baseline data concerning trout habitat requirements in the Midwest. In May 1983, three streams were spot-stocked and three were scatter-stocked, each with 1,200 brown trout. In June and September 1983 and March 1984, trout were collected by electrofishing from eight 0.1 km study subsections in each stream. A habitat survey was conducted in the scatter-stocked streams in July. Recovery and growth of stocked fingerlings at age 1 was similar in the two stocking method groups. Multiple correlation analysis indicated that percentage cobble substrate, mean depth, overhanging vegetation and water type accounted for 84% of the variation in trout biomass in scatter-stocked streams. The data from this study indicate that spot-or scatter-stocking produces no difference in the number of fish recovered or in growth of fish. Therefore, the most economically efficient method, spot stocking, should be used for marginal trout waters in Iowa.

MARSHALL, T. L. and R. P. JOHNSON. 1971. History and results of fish introductions in Saskatchewan, 1900-1969. Fisheries Report No. 8. Saskatchewan Department of Natural Resources. Regina, Saskatchewan. 27 p.

The first brown trout introduction occurred in 1924 with fish originating from Banff, Alberta. Other early introductions came from nearby American states. There was limited success in the Cypress Hill area, yet the brown trout was not as desirable a game fish as brook trout and so its introduction was limited to only 37 waters. The species became established through natural reproduction in seven tributaries of the Missouri and Saskatchewan rivers between 1924 and 1930, although it failed to become established in streams near the Hudson Bay region. It is thought that the survival of the brown trout in the Cypress area is linked to the number of potential predators such as pike, perch, walleye and brook trout. It is likely that the severe climate of northern Saskatchewan is too extreme for the survival of the brown trout. Fourteen plantings failed to establish self-sustaining populations between 1924 and 1967. It is suspected that conditions such as unstable water levels, presence of predators, winter oxygen depletion and lack of tributary spawning streams were responsible.

MARTIN, N. V. 1967. Investigation of European fishes for introduction to Ontario waters. Research Information Paper (Fisheries) No. 32. Ontario Department of Lands and Forests. Toronto, Ontario. 47 p.

In 1966, a tour was made by the author of 9 European countries in the interests of the Ontario Department of Lands and Forests. The main focus of the trip was to study the potential of introducing European fish into Ontario waters, particularly the Great Lakes. Special attention was paid to fish which could withstand certain characteristics of the Great Lakes (with more success than native fish) such as pollution, eutrophication, lamprey predation and an increasing number of coarse fish. Four species of fish were deemed worthy of consideration for introduction: the Danube salmon, the pike-perch, the hybrid sturgeon and the brown trout (*Salmo trutta lacustris*).

The European brown trout is a very plastic species and may live in either lakes or rivers and exists in an anadromous form. This species is found in large lakes in Sweden, Austria, Finland and France and in eutrophic lakes of central Europe. The brown trout requires a good oxygen supply and is highly piscivorous. It is believed that although they are primarily river-spawners, they will reproduce in lakes.

Scientists from numerous countries recommend the introduction of this species into the Great Lakes, yet further investigation is required to determine which stock of the fish is most suited for the Great Lakes. I recommend that this species be given serious consideration for introductory purposes. The early maturity, fast growth, and likelihood of lake spawning habits make this a desirable species. Temperature, oxygen and swim bladder experiments should be carried out preliminary to its introduction. Many of these stocks exist in Europe, those in Finland and Lake Leman, France, are readily available to us and may be the most suitable for introduction. Some further investigations of this species in Europe may be desirable.

MARTINEZ, P., J. ARIAS, J. CASTRO and L. SANCHEZ. 1993. Differential stocking incidence in brown trout (*Salmo trutta*) populations from northwestern Spain. Aquaculture 114 : 203-216.

An allozyme electrophoretic analysis was carried out to evaluate the impact of stocking, and to assess the amount and distribution of genetic variation among brown trout populations in Northwestern Spain. For this purpose, populations from both non-flowing (lagoon and reservoir) and flowing (rivers) waters, stocked and unstocked, were studied in comparison with the hatchery populations used for stocking in this region. Genetic variation was found at 11 out of 35 loci analyzed. Detection of suitable genetic markers, especially the LDH-5* diagnostic locus, permitted us to monitor the incidence of stocking practices. The low viability of stocked individuals within river populations was remarkable, in spite of the long period and great intensity of repopulation. Only four individuals out of 197 analyzed were of hatchery origin. The absence of introgression detected in river populations was accounted for by the extreme Wahlund effect observed at the diagnostic locus LDH-5*. On the contrary, in non-flowing waters a large introgression was revealed. The longer the period of stocking, the larger the introgression detected. Gene diversity analysis demonstrated an important genetic differentiation among natural populations ($G_{ST} = 0.273$), mostly within drainages (86%), which shows an important microgeographical differentiation component. In sharp contrast, the stocking hatcheries exhibited genetic homogeneity ($G_{ST} = 0.014$). Genetic distance ($D = 0.046$) between indigenous and stocking groups apparently shows the presence of two divergent evolutionary lineages of brown trout. The levels of genetic variation were far greater in populations from non-flowing waters and stocking hatcheries as compared with river populations. This fact can be accounted for by the mixed origin of the former populations.

MASON, J. W. and G. D. WEGNER. 1970. Wild rivers fish populations (Pine, Popple and Pike rivers). Research Report 58. Wisconsin Department of Natural Resources. Madison, Wisconsin.

The fish populations and water quality of the Pine, Popple, and Pike Rivers and their tributaries were studied from 1966-1968 to document existing conditions in wild rivers and serve as a basis for future protection and use.

The Pine and Popple Rivers are fast-moving rivers, with falls and rapids, although there are also extensive reaches of quiet, slow-moving water. The Pike River is narrower and deeper, and has more bank and instream cover.

Warmwater fish predominated in the lower Pine. Trout were found in all three rivers, but productivity is restricted by low water fertility, high summer temperatures and cold water temperatures. The north branch of the Pike River us the best stretch of trout water in the wild rivers system. Higher standing crops and better trout reproduction reflect greater productivity.

In future, management emphasis should be placed on maintaining the highest quality fishery possible. Stocking of brown trout will be necessary to facilitate the buildup of this species in the wild rivers. Browns are more likely to grow to larger size and provide a more sustained fishery than the other trout species. Trout should be stocked in areas of river having a high gradient, and in stretches where wild populations are the lowest.

MATHER, F. 1889. Brown trout in America. Bulletin of the United States Fishery Commission 7 (1887) : 21-22.

McCAIG, R. S., J. W. MULLAN and C. O. DODGE. 1960. Five-year report on the development of the fishery of a 25,000 acre domestic water supply reservoir in Massachusetts. Progressive Fish Culturist 22(1) : 15-23.

A creel census began in 1954 at Quabbin Reservoir and has continued ever since. The first stocking of 1,000 each of fin clipped 9-12 inch brook, brown and rainbow trout was made on an experimental basis in March, 1957. The first year returns were 66, 23, and 36%, respectively. Second year returns included only brown and rainbow trout and were 10 and 14%, respectively. In 1958, the closed section of the reservoir was stocked with 1,000 brown and 1,000 rainbow trout. First year returns were 2.4 and 10.1%, respectively.

McCOY, R. W. 1974. Feeding of hatchery-reared brown trout (*Salmo trutta*) in relation to the diel drift in a South Dakota stream. M. Sc. Thesis, South Dakota State University. Brookings, South Dakota. 74 p.

McDOWALL, R. M. 1968. Interactions of the native and alien faunas of New Zealand and the problem of fish introduction. Transactions of the American Fisheries Society 97 : 1-11.

New Zealand possesses a small and unsaturated but peculiar indigenous freshwater fish fauna. In addition, a considerable variety of introduced species is now in competition with the native species and evidence suggests that this is causing depletion of the native fauna. It is considered that low saturation and high isolation of the New Zealand fauna has produced species with low competitive ability. The largely predatory introduced game fishes are of continental origin and their superior competitive ability is leading to displacement of the native species.

Approximately 30 freshwater species have been introduced into New Zealand, with only 12, the majority of the family Salmonidae, having done so successfully. *Salmo trutta*, the brown trout was introduced from stocks in Scotland and Tasmania and has since successfully established itself and become widespread. *S. trutta* and *S. gairdneri*, the rainbow trout, form the basis of the New Zealand freshwater game fishery.

McINTOSH, A. R., C. R. TOWNSEND and T. A. CROWL. 1992. Competition for space between introduced brown trout (*Salmo trutta*) and a native galaxiid (*Galaxias vulgaris* Stockell) in a New Zealand stream. Journal of Fish Biology 41(1) : 63-81.

Increasing circumstantial evidence indicates that the introduction of brown trout (*Salmo trutta*) to New Zealand has caused widespread decline in the native fish populations but few of the underlying mechanisms have been investigated. The possibility of spatial competition was investigated by comparing the microhabitat used by native *Galaxias vulgaris* (Family Galaxiidae) that were sympatric and allopatric with brown trout. A range of microhabitat variables was measured from random locations where *G. vulgaris* were present in the Shag River during the day. *G. vulgaris* preferred coarse substrates, using them as resting places, but showed no other microhabitat preferences. This pattern of microhabitat use did not change in the presence of brown trout although galaxiid densities were considerably lower. Experiments in *in situ* stream channels confirmed that competition for space does not occur during the day even at high galaxiid densities. This situation changed dramatically at night, however, with *G. vulgaris* spending significantly more time in slower areas when trout were present. *G. vulgaris* feeds on drifting invertebrates, so brown trout could affect the galaxiids deleteriously by forcing them to occupy less profitable feeding positions. Interspecific competition for space, perhaps combined with competition for food and predation by trout, could explain declines in *G. vulgaris* populations.

McLAREN, J. B. 1979. Comparative behavior of hatchery-reared and wild brown trout and its relation to intergroup competition in a stream. Ph. D. Dissertation, Pennsylvania State University. University Park, Pennsylvania. 174 p.

Two studies were conducted to relate behavior to the population dynamics involved in stocking in a natural trout stream. The first study compared the behavior of tagged hatchery-reared and wild brown trout (*Salmo trutta*) in a semi-natural stream environment. The second study observed the migration and mortality of hatchery-reared trout superimposed on the wild trout populations residing in Spruce Creek, Huntindon County, Pennsylvania.

Hatchery-reared trout were more active during daylight than wild trout, used cover less, and were more frequently involved in foraging and agnostic behavior. Hatchery-reared trout appeared less sensitive to the effects of physical habitat and season than wild trout. A doubling of density by the superimposition of one group upon the other caused an increase in movements, foraging, and agnostic behavior and a decrease in cover use. The effects of prior residency are discussed.

Hatchery-reared trout integrated into the dominance hierarchy of wild trout, but held no dominance advantage despite their greater frequency of agnostic behavior. Dominance was most closely related to size, and males dominated females during spawning.

Nine weeks after stocking Spruce Creek, emigration and mortality reduced the total standing crop of trout to a level nearly equal to that present before stocking. Total losses of hatchery-reared trout were 1.5 to 2 times greater than that for wild trout. A hypothesis was formulated for the role of behavior, stress physiology, and bioenergetics in the survival of hatchery-reared trout competing with wild trout for food and space.

McLEISH, D. 1984. Techniques for assessing post-stocking life history characteristics of juvenile salmonids. Lake Ontario Fisheries Assessment Unit Report No. 84-3. Ontario Ministry of Natural Resources. Toronto, Ontario. 86 p.

In response to a need for information on the post-stocking life history characteristics of juvenile salmonids stocked into Lake Ontario tributaries a literature review was conducted. Topics considered include the basic life histories of coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), rainbow trout (*Salmo gairdneri*) and brown trout (*S. trutta*), post-stocking: survival, dispersal, residency time, and behaviour of the above species, and carrying capacity. As well, techniques suitable for assessing the above issues were reviewed and optimal approaches recommended. Among the techniques described were marking and tagging, Wolf traps, counting fences, fyke nets, inclined plane traps, electrofishing biotelemetry, habitat analysis, and direct observation. The overall recommendations for such a study were to provide for clear coordination between hatchery and field staff, develop a comprehensive tagging scheme. Give serious consideration to the use of a counting fence as the optional technique, and conduct a preliminary exploratory field season prior to an in-depth analysis.

MERNER, F. H. 1958. A statistical report of the history of the stocking of the Grand River. Ontario Department of Lands and Forests, Southwestern Region, Conservation Officers Projects 1957-1958 : 23-25.

Reports from 1928 to 1957 indicate that 24,000 brown trout fry were planted (between 1933 and 1935) into the Grand River. The stocking of brown trout was a huge mistake. The number which have been caught in contrast to the number planted indicates that no further stocking should be done in this area.

MILLARD, T. J. 1971. An evaluation of planting hatchery-reared brown trout in the Sydenham River, Ontario. M. Sc. Thesis, University of Guelph. Guelph, Ontario. 68 p.

An autumn planting of 4,000 tagged yearling brown trout (*Salmo trutta*) in 1969 resulted in an overwinter survival of 26%, an angler recovery the following year of 8.1% and made up 22% of the March 1970 standing population of the species. August standing populations of brown trout increased from 142 trout/ha (17.6 kg/ha) in 1969 to 360 trout/ha (39.3 kg/ha) in 1970 while angler harvest of the species increased from 61 trout/ha (12.7 kg/ha) at a rate of 0.26 fish per hour to 89 trout/ha (18.5 kg/ha) at a rate of 0.34 per hour.

Using angler recovery and standing population as criteria the planting contributed substantially to the fishery. Actual contribution of stocked trout however, is questioned after detailed analysis of resident population structure and the potential of natural recruitment. It is suggested that the true benefit of stocked trout may be measured by the presence of those stocked fish in excess of the number of resident trout of that size predictable from a normal length distribution curve in waters with self-sustaining populations.

Complexities in evaluating the merits of supplemental hatchery-reared brown trout to existing stream fisheries are examined.

MILLARD, T. J. and H. R. MacCRIMMON. 1972. Evaluation of the contribution of supplemental plantings of brown trout (*Salmo trutta*) to a self sustaining fishery in the Sydenham River, Ontario, Canada. Journal of Fish Biology 4 : 369-384.

An autumn planting of 4,000 tagged yearling brown trout (*Salmo trutta*) in 1969 resulted in an overwinter survival of 26%, an angler recovery the following year of 8.1% and made up 22% of the March 1970 standing population of the species. August standing populations of brown trout increased from 142 trout ha^{-1} (17.6 kg ha^{-1}) in 1969 to 360 trout ha^{-1} (39.3 kg ha^{-1}) in 1970 while angler harvest of the species increased from 61 trout ha^{-1} (12.7 kg ha^{-1}) at a rate of 0.26 fish hour^{-1} to 89 trout ha^{-1} (18.5 kg ha^{-1}) at a rate of 0.34 fish hour^{-1}. Using angler recovery and standing population as criteria the planting contributed substantially to the fishery. Actual contribution of stocked trout, however, is questioned after detailed analysis of resident population structure and the potential of natural recruitment. It is suggested that the true benefit of stocked trout may be measured by the presence of those stocked fish in excess of the number of resident trout of that size predictable from a normal length distribution curve in waters with self sustaining populations. Complexities in evaluating the merits of supplemental plantings of hatchery-reared brown trout to existing stream fisheries are examined.

MILLER, R. B. 1958. The role of competition in the mortality of hatchery trout. Journal of the Fisheries Research Board of Canada 15(1) : 27-45.

The literature on the survival of hatchery reared trout after release in streams is reviewed and the conclusion is reached that survival is poor in lakes and streams where a resident trout population already exists. In streams the deaths of planted trout occur very soon after their release and have been referred to as "delayed mortality". However, a comparison of survivals after planting in occupied and non-occupied streams shows that many of the deaths are not attributable to hatchery background or transportation methods but largely to some aspect of competition with resident trout. Some investigations which have sought to measure the relative survivability of wild and hatchery trout have not used resident wild trout and thus a crucial aspect of the competition has been omitted. Investigations at the Alberta Biological Station test stream, Gorge Creek, are described; in these a significant difference in blood lactic acid levels was found between hatchery trout with and without competition from resident trout. It is hypothesized that introduced trout must compete for niches and for food. In the early stages of this competition they are continuously exercising; they exhaust stores of some metabolit and die either of acidosis or starvation.

MILLER, R. R. and J. R. ALCORN. 1943. The introduced fishes of Nevada, with a history of their introduction. Transactions of the American Fisheries Society 73 : 173-93.

At least 39 species and subspecies of fishes have been introduced into the waters of Nevada since 1873. Of these, 24 kinds are now known to occur in the state. A thorough survey of the exotic fishes has not been made, but specimens or records of introduced species have been kept in the course of rather extensive collecting of the native fish fauna from 1934 to 1943. Consequently, it is believed that the number of introduced species herein enumerated approaches a complete tabulation. Some additions among the sunfishes and catfishes may be expected.

The annotated list is divided into two parts: species now present in the state, and species introduced but never established. The established species constitute about two-thirds of the total number of known native species, but are far outnumbered by the indigenous fishes when all the local subspecies are included.

Specifically, brown trout (*Salmo trutta fario*) were found to occur in the Truckee River about 1906 and was again recorded from that river in 1911-1912. *Salmo trutta* has been planted extensively in the Tahoe area, and the first plant of this species which could have entered Nevada took place in July 1895, when 250 Loch Leven trout, about 3 inches long, were deposited by the California Commission in Webber Lake, Sierra County, California. The outlet of this lake is the Little Truckee River, a tributary of the Truckee River. During 1929-1930, 150,000 eggs and fish were received by applicants in Nevada. In 1930, a total of 50,000 "Loch Leven trout" were planted in Smith Creek, Big Creek and Birch Creek, all located in southern Lander County. Shipments of eggs and fish were again made in 1932-1933 and 1935-1936. In 1941, 210,000 "Loch Leven trout" were planted in Churchill (40,000), Douglas (61,000), Nye (55,000), and Washoe (54,000) counties.

The brown trout is now known to the Reese, Carson, Truckee, and Walker Rivers and numerous mountain streams. Owing to the hatchery practice of mixing strains of brown and Loch Leven trout (*Salmo trutta levenensis*), we were unable to distinguish the two subspecies and refer them both to the above form. It is very doubtful that a pure strain of the Loch Leven has been maintained anywhere in the United States.

MILLS, D. H. and R. M. RYAN. 1973. The movement and benefit to angling of hatchery-reared brown trout released into the River Tweed. Fisheries Management 4 : 109-115.

On March 29th, 1972, 500 hatchery-reared tagged brown trout with an average fork length of 25.0 cm (10 inches) were released into the River Tweed 1.6 km below the town of Peebles. A total of 206 (41.2%) trout were recaptured by 75 anglers between the opening of fishing season on April 1st and September 1st, 1972. The majority (97.6%) of the recaptures were made in the first three months after release and 95.1% were taken within 5 km of the release site. Similar numbers were recaptured upstream and downstream of the release site but the distance travelled downstream (29 km) was greater than that covered upstream (2.6 km).

No further recaptures were made after September 1st and no tagged fish were found in a number of the spawning tributaries in the vicinity of the release site in the autumn and early winter. It is considered that the remaining fish died.

It is felt that the introduction of large hatchery-reared trout on a "put-and-take" basis is of some value on angling association waters where angling pressure is high and the fishing rights extend over more than 5 km (3 miles).

MORAN, P., A. M. PENDAS, E. GARCIA-VAZQUEZ and A. R. LINDE. 1989. Chromosonal and morphological analysis of two populations of *Salmo trutta fario* employed in repopulation. Journal of Fish Biology 35(6) : 839-843.

Two stocks of brown trout employed in repopulating the rivers of Asturias (northern Spain) were morphologically and karyotypically analyzed. Both stocks were significantly different. The foreign stock was less adequate for repopulation than the autochthonous stock.

MORRISSY, N. M. 1972. An investigation into the status of introduced trout (*Salmo* spp.). Department of Fisheries and Fauna, Western Australia 10 : 1-45.

MOTTLEY, C. Mc. 1933. The introduction of brown trout (*Salmo trutta*) into British Columbia. Proceedings of the Fifth Science Congress 5 : 3801-3803.

MOYLE, P. B. 1976. Fish introductions in California. History and impact on native fishes. Biological Conservation 9 : 101-118.

Since 1871, at least 50 species of fish have been successfully introduced into California's inland waters, and numerous transfers of native fishes have been made between isolated drainage systems. Introductions were made of sport fish, commercial fish, forage fish, bait fish, fish for weed and insect control, and aquarium fish. Most of the introductions were authorized, reflecting a dissatisfaction with the native fishes, but in recent years unauthorized introductions have become common. The continuing decline of the native fish fauna seems to be largely the result of habitat change but introduced fishes may have contributed to this decline through competition, predation, and hybridization. The lack of information on the native and introduced fishes of California, and their interactions, demonstrates the critical need for a statewide natural history survey.

Brown trout (*Salmo trutta*) were first introduced from Scotland and Germany in 1872 for sportfishing purposes. Currently brown trout have established themselves in the Klamath system, the Sacramento-San Joaquin system, the Lahontan system, the Death Valley system and numerous south coastal drainages.

MULLAN, J. W. 1956. The comparative returns of various sizes of trout stocked in Massachusetts streams. Progressive Fish Culturist 18 : 35-38.

Brown, brook and rainbow trout (62,680 in total) of various sizes were tagged and planted into five stream drainages to determine their differential survival. Generally there is a significantly greater return of larger fish than smaller fish. The poorest results came from the 6-8 inch yearlings and the highest returns from the 9-12 inch two-year-olds, while those greater than 12 inches provided returns similar to those of the two-year-olds. There appears to be two possible explanations for the difference in size returns of the three trout species: (1) Anglers returned tags to a greater degree from larger trout than smaller trout; or (2) the larger trout were better equipped to deal with stream phenomena such as water velocity and competition, thereby increasing their relative survival.

MULLAN, J. W. 1961. Trout stream management in Massachusetts. Federal Aid Projects F-1-R and F-14-R. Massachusetts Division of Fisheries and Game. Boston, Massachusetts. 100 p.

This report discusses trout stream requirements, why hatchery trout are not a substitute for wild trout, program recommendations including stocking, regulations, habitat improvement, pollution abatement, and stream reclamation.

MULLAN, J. W. and W. A. TOMPKINS. 1959. Trout pond management in Massachusetts. Massachusetts Division of Fisheries and Game. Boston, Massachusetts. 132 p.

This document discusses trout requirements in ponds, the potential trout harvest and pond stocking by studying ponds across the state. The main factor taken into account when stocking trout is the expected proportion of trout which can survive to the following angling season; what number of individual trout are required to provide fishing for more than one year? Long term goals involve the stocking of as many of the 94 available ponds as possible with trout. In order to do this at least 400,000 fall fingerlings (2-5 inches) are needed, including 90,000 brown trout, the rest being rainbow and brook trout. Two year old fish are also needed, 110,000 brown and 60,000 rainbow trout.

Pond-stocking requires knowledge concerning the optimal time to stock the trout. Experiments involving rainbow and brown trout resulted in a 13.6% return for fall-stocked browns and a 2.7% return for fall-stocked rainbows in contrast to 53% for the spring-stocked browns and 49.4% for spring-stocked rainbows. Another study added to the lack of understanding surrounding seasonal plants. Only 2% of February-stocked brown trout were harvested by anglers in comparison with a 42% return to anglers for those stocked in April. There is reason to believe that the mortality of early-stocked trout occurs mainly in Cape ponds. One mainland pond demonstrated a 92% return, collectively, of brown trout planted in the spring and fall of 1956.

MUTENIA, A. and E. SALONEN. 1992. Stocking and recapture of brown trout and landlocked salmon in Lake Enare. p. 128-135. *In* T. Taugbøl, J. Skurdal and P. Nyberg [eds.]. The Management of Fast-Growing Trout Stocks. Proceedings of a Nordic Symposium, 1-3 October, 1991, Lillehammer, Norway.

NAESLUND, I. 1990. Survival, dispersal and growth in 0+ pond-reared brown trout (*Salmo trutta*) released in a northern Swedish stream. Institute of Freshwater Research Drottningholm. 15 p.

During 1985-88, a total number of 15,400 under-yearling (0+) brown trout (*Salmo trutta*) were stocked in Laaktabaecken Brook (Sweden). This brook holds a resident wild population of brown trout. The stocked trout originated from a rapidly growing migratory stock, using Vindelaelven River for reproduction and a big lake for main growth. In 1989, stocked fish accounted for 70-90% and 30-50% of the trout population in the upper and lower parts of Laaktabaecken Brook, respectively. Survival during the first year in the brook varied among years between 15 and 30%. The results of the stocking are discussed emphasizing the importance of stock origin, age and type of rearing of the stocked fish.

NAESLUND, I. 1992. Survival and distribution of pond- and hatchery-reared 0+ brown trout (*Salmo trutta*) released in a Swedish stream. Aquaculture and Fisheries Management 23 : 477-488.

During 1985-88, a total of 17,500 under-yearling (0+) brown trout (*Salmo trutta*) were released in Laktabacken Creek in Swedish Lapland. Of these, 15,500 had been reared in a pond adjacent to the creek during their first summer, where they fed on natural prey. The other 2,000 were conventionally reared hatchery fish fed dry food pellets. All fish were released in the autumn (size 60-70 mm) at the confluence of the pond outlet and the creek. Electrofishing revealed that the stocked fish gradually spread downstream from the point of release at the expense of the resident wild trout population. In 1989, stocked fish accounted for 70-90% and 30-50% of the trout population in the upper and lower stretches of the creek respectively. No long term changes in total trout densities or standing crop occurred as a result of stocking. First year survival of fish released in the creek varied between 15 and 30% over the four years. After three years, 5% of the stocked fish remained in the creek. Planted fish grew less rapidly than wild fish during the first year in the creek. Pond fish had a higher survival rate than hatchery fish and showed a greater propensity to disperse from the point of release.

NAESLUND, I. 1993. Survival and dispersal in hatchery-reared brown trout (*Salmo trutta*) released in small streams. Information Institute of Freshwater Research Drottningholm 1 : 17-41.

During 1989-91, hatchery-reared brown trout (*Salmo trutta*) of different ages were planted in 5 small streams in central Sweden. Trout of five different stocks were used. An attempt was also made to evaluate the importance of stock origin and age for the results of the plantings. In one of the streams trout planted as one-year-olds left the stocking site during the entire summer, mainly in the upstream direction. Emigration of two-year-old trout on the other hand, occurred shortly after the release and were directed both up- and downstream. However, these results were not consistent since trout of the same stocks and ages remained sedentary in another stream. Recaptures of planted trout made 3-12 months after release were concentrated to the area of stocking. Very few fish were caught > 200 m from the site of release. The survival of planted one- and two-year-old trout was relatively high over the first summer but winter survival was very low. It is suggested that stocking with autumn fingerlings might be efficient to support the fishery in streams with poor conditions for natural reproduction. Growth and condition were good indicators on how successful planted fish were in the natural streams as well as their prospects of future survival. Stock differences in survival, dispersal and growth were relatively small and may partly be explained by other factors such as differences in size at release, domestication, etc.

NAESLUND, I. 1998. Survival and dispersal of hatchery-reared brown trout (*Salmo trutta*) released in small streams. p. 59-76. *In* I. W. Cowx [ed.]. Stocking and Introduction of Fish. Fishing News Books, Blackwell Science, Ltd. MPG Books, Ltd. Bodmin, Cornwall, Great Britain.

During 1989-93, hatchery-reared brown trout of different ages (fed fry to age 2+) and from two different stocks were planted into small streams in central Sweden. Emigration from stocked sites, establishment, growth, condition and survival of stocked fish were monitored. Fish age and competition seemed to affect the incidence and direction of emigration. Recaptures of 0+, 1+ and 2+ trout, 2-12 months after release were concentrated within the area of stocking or immediately upstream. Trout stocked as startfed fry in June were more prone to disperse. Age 0+ and 1+ trout increased in length after release, whereas 2+ did not. The condition factor of stocked 1+ and 2+ trout decreased after release and fell to levels well below those of similar sized wild trout. Survival rates of planted 1+ and 2+ trout were relatively high over the first summer, but winter survival was very low. Long-term survival was considerably higher for trout planted at younger stages (startfed fry – autumn fingerlings). It is suggested that stocking with 0+ trout might be an efficient means to re-establish fish stocks or enhance depleted stocks. Stock differences in growth and dispersal were negligible. Recorded stock differences in survival may partly be explained by other factors such as differences in size at release.

NEEDHAM, P. R. 1947. Survival of trout in streams. Transactions of the American Fisheries Society 77 : 26-31.

In spite of extremely heavy expenditures for rearing of hatchery fish, the angling continues to decline. Millions of fish are wasted each year because of lack of facts on how best to utilize properly the product of hatcheries.

Survival studies have indicated that under natural conditions, wild brown trout suffer tremendous natural mortalities amounting to 85% in the first 18 months of life. Over-winter mortalities averaged 60% over a 5-year period. Variable survival conditions rather than the number of young produced in any year, determine the number of fish that later reach catchable size.

Survival studies of hatchery-reared trout indicated heavier losses than with naturally spawned fish. Creel census returns from a number of different waters are presented to support this fact. The conclusion is reached that the angling public must be made aware of the basic economics of hatchery operation, its costs, successes, and failures in order that the field of fishery management again may move ahead.

NEEDHAM, P. R. 1954. The contributions of natural propagation by trout to angling in streams. *In* Proceedings of the 34th Annual Conference of the Western Association of State Game and Fish Commissioners, Las Vegas, Nevada.

Angling customers are slowly coming to understand the enormous expense, the heavy mortality rates and that the great bulk of trout caught in any given state result from natural reproduction – not from hatcheries. Let us for a moment look into this process of natural propagation to appraise its range and extent in two streams: Convict Creek and Sagehen Creek, California.

In Convict Creek, over the five year period from 1939 through 1942, inclusive, natural propagation of brown trout contributed an average of 2,750 fish per mile of stream each year. The number surviving from any brood year varied from 4,905 per mile in 1940 to 1,714 in 1939. Variable survival conditions rather than the number of young produced in any given year determined the number of fish that later survived to be caught. Despite the fact that, in Convict Creek, fish over 6 inches in length averaged between 43 and 77 per mile of stream in the various years covered anglers frequently complained that the stream was fished out. This was not true in any sense of the word – the fish were there but most anglers cannot catch them.

In Sagehen Creek, all stocking of hatchery fish was stopped in 1951. From a creel census conducted during the 1953 season, it was estimated that 1,050 anglers caught 2,976 trout in some five miles of Sagehen Creek. The rate of take per mile was 595 fish.

With respect to stream stocking problems, generally we can state the following facts with assurance. Between 75 and 85% of all trout caught in streams are naturally produced, not the result of plantings from hatcheries. Rearing of 'legals' or 'catchable' trout is expensive and generally over 75% of funds available for trout culture go into the costs of large fish yet usually less than 25% of the anglers in any given state actually share in the catching of legals planted in streams.

NEEDHAM, P. R. 1959. New horizons in stocking hatchery trout. p. 395-406. *In* J. B. Trefethen [ed.]. Transactions of the 24th North American Wildlife Conference, March 2-4, 1959, New York City, New York.

This paper summarizes the findings of over 244 trout planting experiments using marked fish. Statements have been made concerning rainbow, brook and brown trout collectively. Hatchery trout generally give very low returns and it has been found that many planted populations experience an immediate natural mortality following each plant, for no apparent reason. It is recommended that stocking be undertaken only when suitable habitat is available for exploitation, such as with the case of the European brown trout.

NEEDHAM, P. R. 1969. Propagation, stocking and protection. p. 154-179. *In* Trout Streams: Conditions That Determine Their Productivity and Suggestions for Stream and Lake Management. Holden-Day. San Francisco, California.

Recommendations on brown trout stocking are made based upon the size of fish available and the suitability of the receiving stream. Small waterbodies which are lightly fished and include abundant shelter as well as an already-present brown trout population can receive advanced fry or 2 inch fingerling brown trout. Three to 5 inch fingerlings are suitable for planting in streams which are moderately to heavily fished and in lakes where there already exists a well-established population of brown trout. Brown trout 6 inches or larger (yearlings +) should be planted in specific heavily-fished stream areas near large cities or towns.

NEEDHAM, P. R. and D. W. SLATER. 1944. Survival of hatchery-reared brown trout and rainbow trout as affected by wild trout populations. Journal of Wildlife Management 8(1) : 22-36.

The survival of 63 experimental plantings of fingerling brown and rainbow trout under controlled conditions is reported for five seasons, 1939 to 1942, inclusive, at Convict Creek, California. A method is described for the analysis of the effects of competition by wild trout on survival of planted fish; this embodies a food ratio that is shown to correlate with observed survivals.

A gross survival of 63.7% was obtained for brown trout fingerlings, from 1.25-1.56 inches in total length. Larger rainbow fingerlings, 2.88-3.72 inches, under more severe competition, had a gross survival of 46.6%. Other rainbows, 1.32-1.69 inches in length, gave a gross survival of 44.2%. These results were obtained in experimental periods of 89 to 1,151 days.

Plantings of fingerlings are largely ineffectual in streams containing numerous wild trout, since competition and predation prevent any significant survival.

Natural propagation adds large numbers of fish to stream stocks annually. Heavy over-wintering loss of naturally propagated brown trout in their first year of life is clearly identified.

The bearing of these findings on the stocking of streams is discussed.

NELSON, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River system, Alberta. Journal of the Fisheries Research Board of Canada 22(3) : 721-753.

Changes occurred in the abundance and distribution of fishes in the Kananaskis River system, Alberta, in conjunction with fish introductions and hydroelectric development. Data from surveys from 1936 to 1961 indicate the probable chronology of events.
Dolly varden (*Salvelinus malma*), brook trout (*S. fontinalis*), cutthroat trout (*Salmo clarkii*), and rainbow trout (*S. gairdneri*) decreased in abundance, probably due to the introduction of brown trout (*Salmo trutta*), longnose suckers (*Catostomus catostomus*) and white suckers (*C. commersonii*), to the cooling of the Kananaskis River from reservoir construction, and to sport fishing. Hybridization between rainbow and cutthroat trout was also important in the decrease of the latter species. After introduction by man, brown trout, rainbow trout, longnose suckers, white suckers, lake chub (*Hybopsis plumbea*) and longnose dace (*Rhinichthys cataractae*) greatly increased in abundance. Prior to the increase in numbers of white suckers, a reduction in the number of longnose suckers occurred in Lower Kananasis Reservoir. Little change in the distribution of mountain whitefish (*Prosopium williamsoni*), longnose dace, and brook sticklebacks (*Culaea* (*Eacalia*) *inconsians*) occurred over the 25 years. Changes in the physiochemical environment and invertebrate fauna in the reservoirs appeared to be of secondary importance to the interaction among fish in causing the changes in species abundance and distribution.

NEMETH, M. L. and P. W. BETTOLI. 1998. Survival and population size of rainbow trout and brown trout in the South Fork of the Holston River, Tennessee. Presented at the 1998 midyear meeting of the Southern Division of the American Fisheries Society held in Lexington, Kentucky. (Abstract only)

The South Fork of the Holston River in east Tennessee last year received over 900 hours per hectare of fishing pressure. The 20 km tailrace is stocked annually with about 72,000 catchable rainbow trout (*Oncorhynchus mykiss*), 11,000 brown trout (*Salmo trutta*) and some natural reproduction by both species occurs. To obtain more information about the survival of trout in this tailrace, four microtagged cohorts of rainbow trout (>5,800) and one cohort of brown trout (16,670) were stocked between March and September 1997. Survival was investigated by electrofishing each month and conducting a creel survey. Rainbow trout stocked in early summer survived better than trout stocked earlier in the year. Brown trout survived better than rainbow trout stocked at the same time. A change-in-ratio mark-recapture technique estimated the combined population of rainbow trout and brown trout at 56,493 fish in the first 16 km of the tailrace; total trout biomass was estimated to be 214 kg/hectare. The number of wild brown trout less than 270 mm total length was 18,522.

NESBIT, R. A. and J. A. KITSON. 1937. Some results of trout tagging in Massachusetts. Copeia 3 : 168-172.

To determine whether it is more advantageous to plant trout in the autumn or hold them in rearing ponds until the following spring, several thousand rainbow and brown trout were tagged and released in two lots in Massachusetts rivers and ponds, one lot in the fall, the other the following spring. It is estimated from the returns that for a given cost, anglers can be given more and larger fish if trout of legal size are held over winter in hatcheries and planted just before the opening of the season. On average the ratio of percent survival of spring-planted brown trout to fall-planted brown trout was determined to be 3.3:1. When growth increments were measured it was found that the ratio of gained inches in spring-planted brown trout to fall-planted brown trout was 1.8:1. It was also found, incidentally, that the internal tagging method is unsatisfactory on trout.

NETBOY, A. 1979. Ranching salmon in Southern Seas 1: Australia and New Zealand. Sea Frontier 25(4) : 208-213.

Attempts to transplant Salmonidae eggs to Australia and New Zealand are documented. Brown trout has been successfully introduced into Tasmania and has produced generations of fish for stocking Australian and New Zealand waters. Atlantic salmon have become established as a landlocked fish in a few South Island lakes while success in colonizing sea-run salmon has been attained with the introduction of *Oncorhynchus tshawytscha*. Irrigation and hydroelectric schemes are posing problems for the migrating stocks.

NETTLES, D. C., J. M. HAYES, R. A. OLSON and J. D. WINTER. 1987. Seasonal movements and habitats of brown trout (*Salmo trutta*) in southcentral Lake Ontario. Journal of Great Lakes Research 13(2) : 168-177.

During 1980-82, the movements, seasonal locations, and habitat preferences of brown trout in southcentral Lake Ontario were examined using radio telemetry and vertical gill nets. In fall and spring 85% of the 28 brown trout tracked by radio moved east from tagging sites. Movements frequently centered around original stocking sites, streams, and power plant outflows. Fish moved farther in spring (4.4 ± 2.5 km/day) than in fall (2.4 ± 1.7 km/day) seasons, but short-term movement rates did not differ between seasons (0.4 ± 0.1 km/hour in spring vs. 0.4 ± 0.3 km/hour in fall). Females moved farther and faster than males in the fall. Brown trout generally occupied shallow waters < 1 km from shore; 81% of temperatures occupied by trout were between 8-18° C in spring (10.6 ± 2.3° C) and fall (10.1 ± 3.9° C), but turbidity appeared to influence presence or absence of trout near shore on a daily basis.

NICHOLLS, A. G. 1958. The population of a trout stream and the survival of released fish. Australian Journal of Marine and Freshwater Research 9 : 319-350.

The fish population of a river system was studied by electro-fishing in 25 places, after which 1,000 marked yearling brown trout (*Salmo trutta*) were released at each of the 10 sites. In a re-examination 8-9 months after the release it was estimated that about 10% of these were surviving; the survival after 18 months was estimated to be below 5%, and the survival to takeable size, at about 3 years of age, at 2%. At no site were the younger age groups of the natural population truly represented in either season, but the numbers of older fish in the second season were greater than those of the corresponding year classes in the preceding season, showing that the streams receive recruitment of younger fish from other sources. Some evidence is produced to show that "nursery" streams provide the sources of recruitment. The average annual mortality for fish of 2 and 3 years of age is estimated at from 70-80% for the system. It is estimated that there were about 45,000 takeable fish in this river system at the beginning of each season. It is shown that the mean lengths of trout decrease with increasing density of population, and that there is a curvilinear relationship between population density and total weight of all fish per acre. The standing crop of trout at different sites ranged from 1 to 182 lb/acre over the two seasons. The condition factor showed a decrease with increasing age of the fish, and the released fish had a lower factor than resident fish of the same age at all sites. In general there was a relationship between the depth of the water and the length of the fish, sections over 14 inches deep having greater populations of larger fish. A study of the ability of each section of stream to carry fish, based on the lengths and condition factors of the fish, the number and weight of the population per acre, and the ability of each section to absorb additions to the population, shows that where populations were low, conditions were less favorable to the growth and survival of fish.

NIELSEN, C., S. S. MADSEN and B. TH. BJÖRNSSON. 1999. Changes in branchial and intestinal osmoregulatory mechanisms and growth hormone levels during smolting in hatchery-reared and wild brown trout. Journal of Fish Biology 54 : 799-818.

Evidence of smolting was studied in Danish hatchery-reared brown trout (*Salmo trutta*). Twenty-four hour seawater (SW) challenge tests (28‰, 10° C) at regular intervals showed that maximal hypo-osmoregulatory ability developed within a 3-4 week period in March and April. The improved ability to regulate plasma osmolality, muscle water content and plasma total [Mg] developed asynchronously, indicating that developmental changes in the gill, the gastrointestinal system and the kidney may not necessarily concur during smolting. Gill Na^+,K^+-ATPase activity peaked in April at the time of optimal hypo-osmoregulatory ability. Na^+,K^+-ATPase α-subunit mRNA level in gills was unchanged from January until April, but decreased in May in parallel with a decrease in the activity of the enzyme. In the middle region of the intestine, Na^+,K^+-ATPase activity increased in February and remained high until April. In the posterior region of the intestine, the activity was stable from January until April after which it decreased. *In vitro* fluid transport capacity, J_v, was low until late March, when it increased fivefold until early May. Drinking rate in fish transferred to SW for 24 hours surged during spring. Na^+,K^+-ATPase activity in the pyloric caeca was elevated from March until May, and increased in response to SW transfer in June, suggesting a hypo-osmoregulatory function of the pyloric caeca. Plasma GH levels surged in FW trout during spring, concurring with the increase in gill Na^+,K^+-ATPase activity and SW tolerance, but peaked in May when gill Na^+,K^+-ATPase activity and SW tolerance were regressed. GH levels were generally low in SW-challenged fish, and there was no consistent effect of 24 hour SW exposure on GH levels. In wild anadromous trout, gill Na^+,K^+-ATPase activity varied seasonally as in hatchery-reared fish, but peaked at higher levels suggesting a more intense smolting in fish living in their natural environment.

NIELSEN, L. A., W. T. KENDALL and L. A. HELFRICH. 1980. Comparison of angler use and characteristics at three catchable trout fisheries in Virginia. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 34 : 330-340.

Creel census data for three catchable trout (rainbow, brook and brown trout) fisheries in Virginia revealed that desirable attributes of the fisheries increased from a lightly stocked stream to a lightly stocked lake to a heavily stocked stream. Total effort, participation by non-local anglers, evenness of seasonal use, catch rate, and return rate all were higher for the heavily stocked stream than for the lightly stocked stream. For the trout lake, total effort and participation by non-local anglers were similar to the heavily stocked stream, but catch per effort, return rates of stocked fish and seasonal distribution of effort were similar to the lightly stocked stream. Most anglers at the lake fished from shore so that a large portion of the potential fishing area was not utilized. Management of catchable trout fisheries may provide higher fishing value if streams are managed so that stocking density, stocking frequency, accessibility of angling, publicity and opportunities for associated outdoor recreation are maximized.

NIELSON, R. S. 1953. Should we stock brown trout? Progressive Fish Culturist 1953 : 125-126.

Prior to the turn of the century there was a veritable rash of fish transplantations throughout the world. Brown trout were among many European species that were widely distributed at that time and both strains of the brown trout – the Loch Leven trout (*Salmo trutta levenensis*) from Scotland, and the von Behr or German brown trout (*Salmo trutta fario*) from Germany, were introduced into the United States.

A positive credit for these trout is based upon the fact that they are well adapted to warm water lakes and to warm slow moving streams that are not particularly favored by native species. Another more dubious credit is derived from the fact that brown trout seem to maintain themselves more efficiently in the face of heavy angling pressure than most other species of trout because they are more difficult to catch.

On the debit side, it can now be said with certainty that brown trout are also comparatively well adapted to cold water lakes and to cold rapidly flowing streams where these fish are in absolute competition with native species.

What, then, is the answer to the question "should we stock brown trout?" If nothing else has been learned from more than half a century of experience it should be this: the distribution of exotic species of trout should be attended with great care and rigidly controlled to prevent danger to and displacement of native stocks that have demonstrated their value to recreational fisheries.

NIHOUARN, A., J. P. PORCHER and G. MAISSE. 1990. Comparison of the performances of two strains of brown trout (*Salmo trutta*) (domestic and hybrid wild x domestic) introduced as fry in a brook. Bulletin Français de la Pêche et de la Pisciculture 319(4) : 173-180.

The production of an interstrain hybrid of brown trout (*Salmo trutta*) (wild male x domestic female) was sometimes proposed for stocking wild waters. Previous works give evidence of a poorer performance of this hybrid in the hatchery than the maternal strain (domestic male x domestic female). The present study compares the results of planting hybrid and domestic alevins, introduced in a brook where the natural reproduction involved the use of fine sediments. The stocking was made during 2 successive years in May. Electrofishing surveys conducted in May and October of each year show that the implantation is the same for the 2 origins. In all the study areas, domestic alevins keep the length superiority obtained during the hatchery stage.

NIKINMAA, M., A. SOIVIO, T. NAKAII and S. LINDGREN. 1983. Hauling stress in brown trout (*Salmo trutta*): Physiological responses to transport in freshwater or saltwater and recovery in natural brackish water. Aquaculture 34 : 93-99.

Brown trout were transported in dilute NaCl (0.6%) or fresh water, and allowed to recover in natural brackish water (salinity 0.6%). Transport in freshwater caused an increase in blood haemoglobin concentration, and decrease in mean cellular haemoglobin concentration, plasma osmolality, hyperglycaemia, muscle fat and liver glycogen content. Although present, these changes were markedly smaller in the animals transported in NaCl solution. Recovery in brackish water abolished the differences between the two groups, and the physiological parameters reached a steady-state level within a week of recovery.

NIVA, T. 1999$_a$. Effect of seasonal patterns in energy allocation on natural mortality in lake-dwelling juvenile brown trout with respect to prey utilization. p. 1-5. *In* Fish Feeding Ecology and Digestion: GUTSHOP '98.

Using field data, seasonal patterns are described in feeding and energy allocation for lake-dwelling juvenile brown trout (*Salmo trutta*) in northeastern Finland, at 66 degrees latitude. The aim was to detect whether energy allocation between growth and storage was different at different levels of natural mortality, and how allocation to these targets was linked to seasonality and prey utilization. A variance model analyzed differences in mortality with respect to stocking lake and age of the fish at release. The field experiment was designed so that sources of variation from genetics, hatchery treatment, and stocking density were kept minimal for fish at release. In addition, the study lakes were very similar with repect to area, depth and water quality. The ecological responses measured were mainly due to variation in food utilization across lakes and years. Energy allocation responses to seasonality in respect to differences in feeding conditions, and the finding that highest survival was found for 3-year-old trout indicated that several life history traits of this brown trout were adapted to maximize smolt survival in an unpredictable lake environment. Temperature independent and seasonally induced compensatory growth may be the general pattern in migratory salmonids during their main growth phase in the sea or lakes.

NIVA, T. 1999$_b$. Relations between diet, growth, visceral lipid content and yield of the stocked brown trout in three small lakes in northern Finland. Annales Zoologici Fennici 36(2) : 103-120.

Diet, growth, visceral fat accumulation and a consecutive yield of the stocked brown trout (*Salmo trutta*) (four age groups, initial weight range 29-373 g) were studied in three small Finnish lakes in 1991-1996. The average growth rate and visceral lipid content were significantly greater in lakes and years when the trout fed mainly on small fish, such as vendace (*Coregonus albula*), ninespine stickleback (*Pungitius pungitius*) and one-summer-old perch (*Perca fluviatilis*) than their insectivorous conspecifics. The stocked trout initially foraging unpreferred food items shifted rapidly to feed on small fish when their stocks became abundant. Piscivorous trout increased their visceral lipids prior to winter whereas in insectivorous fish these decreased gradually during the growth season which probably caused increased overwinter mortality. Therefore, relative yields were significantly higher for piscivorous than insectivorous trout. On the other hand, the largest trout at release showed the poorest performance irrespective of the quality of the foraging environment.

NIVA, T. and K. JUNTUNEN. 1993. An estimation of brown trout stocking productivity based on Carlin- and coded-wire taggings on the Lake Kitkajarvi and the River Kitkajoki, Northern Finland. Suomen Kalatalous 59 : 85-101.

NORTH, E. 1983. Relationships between stocking and anglers' catches in the Draycote Water trout fishery. Fisheries Management 14(4) : 187-198.

The trout fishery at Draycote Water was investigated during the 1980 fishing season. Fish stocked were batch-marked according to the date of introduction by freeze branding, and catch data were obtained by the cooperation of the anglers. Population estimates were made at the end of the fishing season using gill nets and mark-recapture techniques.

Of the 32,960 marked brown and rainbow trout stocked, 69.8% were caught and declared by anglers. Returns of rainbow trout were better (78.1%) than those of brown trout (44.2%). Over 90% of all fish caught were taken within 45 days of stocking. Catch-per-unit-effort fluctuated widely but was closely associated with the stocking of fish. Catchability (Q) of stocked fish was found to diminish rapidly with time after stocking.

At the end of the fishing season the estimated population of marked trout was 4,045 (2 x SE = 250), compared with a theoretical number (stock less than total catch) of 10,802, giving a mean daily apparent natural mortality, made up of the true natural mortality plus the undeclared catch, of 1.36%.

NUBERG, P. and P. MOSSBERG. 1978. Stocking brown trout (*Salmo trutta*) of different strains in small acid and humic forest lakes. Information Institute of Freshwater Research Drottningholm 9. 18 p.

NUHFER, A. J. 1996. Relative growth and survival of three strains of rainbow trout and three strains of brown trout stocked into small Michigan inland lakes. Fisheries Research Report No. 2026. Michigan Department of Natural Resources. Ann Arbor, Michigan. 24 p.

The relative growth and survival was assessed over a three year period for three strains of rainbow trout (*Oncorhynchus mykiss*) stocked as yearlings into two small oligotrophic lakes. Their relative tendency to emigrate was evaluated in one lake that had an outlet. The strains tested were Shasta (SH), Eagle Lake (EL) and Michigan steelhead (STT). Relative growth and survival was similarly evaluated for three strains of brown trout (*Salmo trutta*) stocked into four small oligotrophic lakes. Brown trout strains examined were Wild Rose (WR), Seeforellen (SF) and Plymouth Rock (PR). No significant differences in survival of rainbow trout strains were found. However, point estimates of survival and standing crop in both lakes were highest for STT, intermediate for EL and lowest for SH. EL rainbow trout were significantly heavier than STT in four of the five samples collected over a three year period from both lakes. EL trout were consistently heavier than SH in both lakes during the first 30 months after stocking. In West Lost Lake, EL were significantly larger than SH in all samples collected through 30 months after stocking, but at East Fish Lake weight differences were significant only for the sample collected ten months after trout were stocked. After 37 months residence, EL and SH in both lakes were of similar size. Overall results indicated few significant differences in growth of SH and STT. There was little evidence that any rainbow trout strain tested was more likely to emigrate from the experimental lake which had an outlet. Mean lengths and weights of WR and SF brown trout were similar during sampling periods from 6-37 months after stocking. WR and SF brown trout strains produced far more legal sized fish (> 254 mm TL) than PR by six months after stocking because they were larger when stocked. There were no significant differences in survival or standing crops among brown trout strains after 30 months residence in the study lakes. When Ford Lake survival estimates were excluded from ANOVA analysis, survival of PR was significantly higher than for SF or WR and survival of WR was higher than for SF after 30 months residence. After 30 months residence there were no significant differences in standing crops among brown trout strains.

NUHFER, A. J. , R. N. LOCKWOOD and J. L. DEXTER. 1996. Selected factors affecting rate of loss of fine-fabric Floy tags when applied to yearling brown and rainbow trout. Fisheries Report No. 2025. Michigan Department of Natural Resources. Ann Arbor, Michigan. 20 p.

We tested the potential suitability of FD-68B fine-fabric Floy tags for determining relative survival or angler recovery of different strains of small yearling rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*). We determined tag loss in small inland lakes for up to 37 months after tagging. We determined effects of Floy tagging, fin clipping, and tag color on brown trout mortality and effect of tag color on tag loss rates for up to 7 months. Rainbow trout lost tags at a rate of approximately 1% per month over 37 months. Brown trout lost tags at a rate of 1.6% per month over 37 months. Relative survival of three rainbow trout strains through 30 months was accurately ranked based on tag recovery. However, due to tag loss, relative survival through 30 months of three brown trout strains was not accurately ranked based on tag recovery. Significant differences in survival among brown trout strains were detected based on fin clip recoveries but no differences could be detected when survival was estimated from tag recoveries. Inverse relationships between tag loss and total trout length (TL) at tagging appeared to be a major cause of variation in tag loss between different trout strains. Small brown trout (<16.5 cm mean total length) tagged and stocked into a shallow, weedy spring pond lost 54% of their tags within 101 days after stocking during 1990 and 57% within 210 days after stocking in 1991. High tag loss by these trout was attributed primarily to their small size at tagging and anatomical location of tag insertion. Our data suggested that insertion of tags beneath the posterior half of the dorsal fin, where pterygiophores are smaller than the anterior half, contributed to poor tag retention. Brown trout tagged with orange or brown tags, lost tags at the same rate over a 210 day period. Daily mortality period of four groups of brown trout: fin clipped and tagged with orange tags, fin clipped with brown tags, fin clipped only and unmarked fish, were not significantly different through 210 days of residence in the spring pond.

Our findings suggested that the fine-fabric Floy tags were poorly suited for evaluations of relative survival or return to creel of different trout strains or species when tagged trout were <17-cm long at tagging. Tag loss varied by strain and by species of trout, size of fish, and anatomical location of tag insertion. Because of this variability, differences in the numbers of tags returned from different strains or species could not be readily attributed to performance differences between groups. Fine-fabric Floy tags may be suitable for short-term evaluations of angler harvest of rainbow trout (≥ 17 cm TL) in lakes where most fish are caught within the first six months after stocking.

OATIS, P. H. 1970. Effects of domestic and industrial pollution on the ichthyofauna of the Millers River, Massachusetts. Massachusetts Cooperative Fishery Research Unit. M. Sc. Thesis, University of Massachusetts. Amherst, Massachusetts. 83 p.

The effects of pollution on the trout stocking policy is included with the thesis.

O'DONNELL, J. 1945. A four-year creel census on the Brule River, Douglas County, Wisconsin. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 37 : 279-303.

Creel censuses were conducted during the trout seasons of 1936, 1943 and 1944 to determine fishing intensity or concentration of anglers, catch, rate of catch, and effectiveness of 1943 and 1944 plantings of marked (tagged and fin-clipped) legal-sized trout in the Brule River. The brook trout catch has continued to decline since 1936 while the brown trout have entered the creel in increasing numbers during the same period, even though plantings of the latter species have always been light. Stocking of brown trout stopped entirely three years ago. In 1936, the catch of resident (unmarked) brook trout was 57.5%, brown trout 10.2%, and rainbow trout 32.8%, as compared with the 1944 catch of brook trout 34.3%, brown trout 35.2% and rainbow trout 32.8%. Returns from a spring plant of 2,000 marked legal-sized brook trout in 1943 amounted to 28.7%. The captures from a spring plant of 6,500 legal brook trout in 1944 amounted to 27.7% of the plant, but made up 50.0% of the total catch of all species of trout for the year. Very few of the trout stocked in 1943 were caught in 1944 since only one brook trout from a plant of 2,000 and only 11 rainbow trout from a plant of 1,665, were noted by census clerks. The catch per fisherman-day of resident trout has declined steadily since 1936; the numbers of trout per fisherman were 4.4, 2.8, 2.8, and 2.4 for the years 1936, 1940, 1943 and 1944, respectively. When the tagged legal-sized trout are included, the catch per fisherman-day for the last two years has amounted to 4.7 and 4.8 trout. It is concluded that the stocking of legal-sized trout during the spring and early season provides a return to the angler in fishing satisfaction which the previous extremely heavy plants of fingerling trout did not provide.

O'DONNELL, S. 1996. Fish research for Oklahoma waters: Evaluation of the brown trout stocking success in the lower section of the Mountain Fork River below Broken Bow Reservoir. Oklahoma Department of Wildlife Conservation. Oklahoma City, Oklahoma. 30 p.

The objective of this study was to evaluate the stocking success, growth rates, and calculate relative abundance of brown trout year-classes through 1995, by electrofishing in the lower Mountain Fork River below Broken Bow Reservoir.

O'GORMAN, R., R. A. BERGSTEDT and T. H. ECKERT. 1987. Prey fish dynamics and salmonine predator growth in Lake Ontario, 1978-84. Canadian Journal of Fisheries and Aquatic Sciences 44 (Supplement 2) : 390-403.

The size of hatchery-reared brown trout (*Salmo trutta*) and coho salmon (*Oncorhynchus kisutch*), one year after release in Lake Ontario, declined when the stocking of salmonines was increased between 1978 and 1984. The principal prey species, alewife (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*), failed to show the expected, predator-induced downturn in abundance. Instead, rainbow smelt remained moderately abundant and alewives very abundant. The authors hypothesize that abundant adult alewives suppressed production of young-of-the-year fish (necessary prey for salmonines during their first year in the lake) through competition for limited zooplankton production, and thus impeded the transfer of energy from the lowest trophic level to young salmonine predators.

O'GRADY, M. F. 1982. The importance of genotype, size at stocking and stocking date to the survival of brown trout (*Salmo trutta*) released in Irish lakes. p. 178-191. *In* European Inland Fisheries Advisory Commission Symposium of Stock Enhancement in the Management of Freshwater Fisheries. Budapest, Hungary.

The relative success of a series of brown trout (*Salmo trutta*) stocking experiments in a range of Irish lakes are outlined. Data indicate that, in the case of yearling plantings, the direct offspring of wild trout survived in greater numbers than an inbred strain of trout. Size on stocking can be more important than genotype in relation to plantings of two-year old fish. The larger individuals tend to survive in greater numbers and contribute more to angling catches. Repeated stocking of trout in spring and autumn indicate that the former are more successful both in terms of survival and subsequent angling catches.

O'GRADY, M. F. 1983. Observations on the dietary habits of wild and stocked brown trout (*Salmo trutta*) in Irish lakes. Journal of Fish Biology 22 : 593-601.

The dietary habits and feeding rates of wild and stocked brown trout were compared for populations in a number of Irish lakes. Wild trout and stocked fish, which had been present in a fishery for 12 months or more, tended to feed on the same dietary items at similar rates. Stocked fish in their immediate post-planting period (1-14 days) ate less than both the wild trout and established planted trout. In some instances recently stocked fish appear to have a preference for surface food items. They also consumed stones and detritic material. Data indicate that stocked fish adopted a natural diet in less than 5 months. Results are discussed in relation to angling crops of wild and stocked fish and the comparative success of autumn and spring plantings of salmonids.

O'GRADY, M. F. 1984$_a$. The effects of fin clipping, Floy tagging, and fin damage on the survival and growth of brown trout (*Salmo trutta*) stocked in Irish lakes. Fisheries Management 15(1) : 49-58.

The results of a series of experimental stocking programmes designed to assess the effects of fin clipping, fin damage and Floy tags on the survival and growth of brown trout (*Salmo trutta*) are presented. Data indicate that even a single fin clip can seriously reduce survival and also retard the growth of fish. Trout released with extensive fin damage also exhibited poorer survival and growth patterns than their unmarked counterparts. The growth and survival of trout (≥ 18 cm) does not appear to have been altered by Floy tagging.

O'GRADY, M. F. 1984$_b$. Observations on the contribution of planted brown trout (*Salmo trutta*) to spawning stocks in four Irish lakes. Fisheries Management 15(3) : 117-122.

The relative proportions of mature wild and stocked brown trout in four Irish lakes were compared with their subsequent occurrence in spawning runs. Data indicate that stocked trout, of two strains, did not run the streams to spawn in significant numbers. Considerable stocks of introduced fish, which had shed their milt or eggs, were present in these lakes in springtime. The failure of brown trout stocked in lakes to run spawning streams subsequently had not been recorded previously.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1981. Report of the brown trout management working group. Brown Trout Management Working Group. Ontario Ministry of Natural Resources. Toronto, Ontario.

Brown trout were first stocked in Ontario in 1913. Stocking of brown trout in Ontario ceased in 1961 because brown trout were found to be a source of furunculosis in Ontario hatcheries. In response to demands by the public that Ontario adapt a proactive role in the management of brown trout in the Great Lakes basin, this working group was struck.

The working group advocates that stock selection and management for brown trout in Ontario should always work toward the establishment of self-sustaining populations. Where fish stocking is needed , strains of wild rather than domestic stocks should be used, spring yearlings should be planted instead of fall fingerlings, and scatter plantings will effect dispersal and increase survival. It is apparent that stocking methods, including timing and distribution of brown trout into lakes and streams, require further investigation and development.

Brown trout which are produced as a result of habitat enhancement/management will cost less than those reared in hatcheries and it is suggested that this mode of stock enhancement be prioritized. However, there exist many stocking options for the brown trout:

- The brown trout can be planted into streams which have a poor previous record of post-stocking survival for brook trout and managed as a put-and-take fishery.
- Private ponds may be planted with brown trout instead of rainbow trout.
- Brown trout may be planted into the Great Lakes to provide fishing opportunities for anglers.
- Streams which are unsuitable for other salmonids may be stocked with brown trout to create a self-sustaining population.
- Brown trout may be planted to improve the carrying capacity and natural survival of an existing population.
- Yearlings should always be planted rather than eggs, fry or fingerlings.

ONTARIO MINISTRY OF NATURAL RESOURCES 1986. Draft report of Lake Ontario Predator Working Group, September 1986. Draft. Ontario Ministry of Natural Resources. Toronto, Ontario.

It is recommended that in order to maintain the Lake Ontario predator biomass at a constant level annual releases of each fish species do not change significantly. Using the relative predatory impact of each species, as was calculated for Lake Michigan as a basis, impact-on-forage stocking ratios were developed for Lake Ontario salmonids. It is suggested that the ratios be as follows: 1.90 chinook salmon : 1.58 Atlantic salmon : 1.43 lake trout : 1.28 brown trout and rainbow trout : 1.00 coho salmon; assuming all fish are stocked as spring yearlings, with the exception of chinook salmon which are stocked as lake spring fingerlings.

ONTARIO MINISTRY OF NATURAL RESOURCES. 1999. Stocks catalogue. Fish and Wildlife Branch, Fish Culture Section, Ontario Minstry of Natural Resources. Peterborough, Ontario.

The Ganaraska River strain of brown trout is that which is used in Ontario provincial hatcheries. The fish from this stock have demonstrated the ability to remain in the fishery for up to 5 years and they contribute significantly to Lake Ontario shore fisheries. Although, there is little tendency to smolt the Ganaraska stock does reproduce naturally. It is recommended that this strain be planted in the Great Lakes to either rehabilitate or establish populations in tributary streams or to provide hatchery-dependent fishing opportunities. This strain may also be used in inland rivers and streams for introductory stocking with the hope of establishing self-sustaining populations.

OWENS, S. J. and P. W. BETTOLI. 1998. Characteristics of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) growth in the South Fork of the Holston River, Tennessee. Presented at the 1998 Southern Division of the American Fisheries Society midyear meeting, Lexington, Kentucky.

The South Fork of the Holston River, Tennessee, has been managed by the Tennessee Wildlife Resources Agency as a tailwater trout fishery since 1952, but the growth of salmonids in that system has not been studied. Four cohorts of about 6,000 rainbow trout (*Oncorhynchus mykiss*) and 16,000 brown trout (*Salmo trutta*) were microtagged and stocked at different times in 1997. Monthly electrofishing samples were collected between March and November 1997. Each trout was measured, weighed, and checked for the presence of a microtag. Growth rates for the different cohorts of microtagged trout were calculated and compared. Mean growth of the four rainbow trout cohorts averaged 13-22 mm/month and 25-51 g/month, and growth rates varied among cohorts ($P > 0.05$). Hatchery-reared brown trout grew 11 mm/month and 20 g/month; wild brown trout grew 11 mm/month and 18 g/month. Hatchery brown trout grew at similar rates to resident wild brown trout. Hatchery trout grew faster in this system than trout studied in other Tennessee tailwaters. Rainbow trout stocked later in the season showed a trend for faster growth in weight than earlier stocked trout. Except for rainbow trout stocked in July, the relative weight of stocked fish declined consistently over time.

PAINTER, D. R. and T. J. KWAK. 1998. Factors influencing brown trout reproductive success in Ozark tailwater rivers. Presented at the 1998 American Fisheries Society annual meeting, August 23-27, 1998, Hartford, Connecticut. (Abstract only)

Brown trout (*Salmo trutta*) reproductive success in White River tailwaters is highly variable, resulting in the need for supplemental stocking. A better understanding of physical and biotic factors affecting survival among tailwaters will facilitate fisheries composed of greater proportions of wild populations. Estimated fecundity and condition factors from pre-spawned female brown trout were significantly lower at a tailwater known for reproductive failure, while there was no difference among sites with higher reproductive success. Brown trout spawning occurred from October 11 to November 23, 1996, and juvenile emergence began February 23, 1997. There were no significant differences in spawning gravel quality or percent fines obtained by freeze-core sampling. Significant among-site differences were found for spawning and juvenile microhabitat variables; however, variables fell within optimal ranges reported in the literature. Juvenile density differed significantly among sites, but not their size or condition. No brown trout eggs or juveniles were found in 418 Ozark sculpin (*Cottus hypselurus*) stomachs examined. Ozark sculpin density was highest, and benthic invertebrate abundance was lowest at the tailwater known for reproductive failure. Examination of influential factors may lead to improvement of trout reproductive success and increase the proportion of wild trout in these systems.

PALM, S. and N. RYMAN. 1999. Genetic basis of phenotypic differences between transplanted stocks of brown trout. Ecology of Freshwater Fish 8(3) : 169-180.

We present results from an experiment testing for the existence of genetically based phenotypic differences among populations of brown trout (*Salmo trutta*) born and raised under entirely natural environmental conditions. Genetically tagged individuals from two stocks (A and B) were introduced into a drainage system in Sweden previously void of brown trout, and the first generation (F_1) progeny were sampled from two lakes during nine consecutive years. Phenotypic differences among groups of progeny (A, B, and the AB hybrid) are expected to reflect genetically determined dissimilarities between the introduced stocks.

Phenotypic differences among progeny groups were observed for age at maturity and for migratory and reproductive behavior, and these characters are apparently determined by genetic factors to an extent that permit their detection even in the presence of confounding and naturally occurring sources of variation such as lake, age, cohort and year of sampling. There was also significant variation among offspring groups with respect to body size (length), but only a small proportion of the total variation in size could be attributed to stock differences. These genetically based stock characteristics may represent local adaptations, and the fishery management implications of these findings are discussed.

PAWSON, M. G. 1982. Recapture rates of trout in a 'put-and-take' fishery: Analysis and management implications. Fisheries Management 13(1) : 19-31.

Stock, catch and effort data for a small 'put-and-take' trout fishery were analysed to determine a stocking strategy fulfilling the needs of both anglers and management. The assumptions of negligible 'natural' mortality and constant 'catchability' implicit with stock determinations using catch-per-effort and catch succession techniques were tested, and found to be largely upheld in this instance. The calculations of optimal stocking rates based on these results are described and indicate that frequent restocking with sufficient fish to maintain a stock capable of giving the desired catch per effort is preferable, both from the viewpoint of angler satisfaction and to facilitate management of the fishery.

PAWSON, M. G. 1991. Comparison of the performance of brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) in a put-and-take fishery. Aquaculture and Fisheries Management 22 : 247-257.

Stock and catch statistics for a small (5.5 ha) lowland put-and-take fishery have been used to investigate the relative catchability of brown (*Salmo trutta*) and rainbow (*Oncorhynchus mykiss*) trout. Brown trout were consistently less vulnerable to fly fishing than rainbows and were particularly difficult to catch between mid-June and September. As a consequence, the turnover of rainbow trout stock was more rapid than that of brown trout but eventual recapture levels of both species were similar at around 90% of the fish stocked. In these circumstances, brown trout could be regarded as a long term investment for fishery managers with rainbows providing more 'instant' sport.

PECK, J. W. 1992. The sport fishery and contribution of hatchery trout and salmon in Lake Superior and tributaries at Marquette, Michigan, 1984-87. Fisheries Research Report No. 1975. Michigan Department of Natural Resources. Lansing, Michigan.

A creel survey of the sport fishery in Lake Superior and three tributaries (Dead, Carp, and Chocolay rivers) at Marquette, Michigan, during 1984-87 revealed an intensive fishery, mainly for naturally produced trout and salmon. Annual fishing effort in the lake and three tributaries averaged 119,000 and 37,000 angler hours, respectively. Most effort in the lake was by boat (68-84%) but fishing from shore was substantial (16-20%), especially in Marquette Bay (41-51%). Ice-fishing effort fluctuated considerably among years (1-14%). Effort in the tributaries was mainly by shore angling (69-100%). The Lake Superior sport fishery was particularly active during March-September, with the highest effort in April. Lake Superior anglers fished an average 3.2 hours per trip, whereas those fishing the tributaries averaged 2.1-2.5 hours per trip. Fishing in the tributaries was mainly during April-May and September-October. More fishing was done in the Dead River than in the Carp and Chocolay rivers combined. Over 90% of all anglers surveyed were from Marquette County. Anglers sought mainly lake trout and coho salmon in Lake Superior, and rainbow trout and coho salmon in the tributaries. Salmonid fishes made up most of the catch and were represented by eight species of trout and salmon, one trout hybrid, and two species of whitefish. Most numerous in the catch were coho salmon, lake trout, and round whitefish in Lake Superior, coho salmon and chinook salmon in the Dead River, rainbow trout and coho salmon in the Carp River, and coho salmon and rainbow trout in the Chocolay River. Most trout and salmon caught in Lake Superior were immature, whereas those caught in the tributaries were usually mature fish. In the Lake Superior sport fishery, lake trout averaged 23.5 inches, 4.4 pounds, 8 years old, and the highest monthly catch was in August; coho salmon averaged 16.6 inches, 1.4 pounds, 2 years old and the highest monthly catch was in April; chinook salmon averaged 25.4 inches, 6.8 pounds, 3 years old, and the highest monthly catch was August; rainbow trout averaged 21.2 inches, 3.6 pounds, 4 years old and the highest monthly catch was in May; brown trout averaged 17.2 inches, 2.2 pounds, 3 years old, and the highest monthly catch was in March; splake averaged 13.6 inches, 0.9 pound, 2 years old and the highest monthly catch was in February.

The majority of fish in the catch were naturally produced with the exception of splake and Atlantic salmon at all sites, coho salmon in the Dead River, and brown trout in the Carp River. Hatchery coho salmon provided 80% of the coho catch in the Dead River but 6% or less in Lake Superior, and the Carp and Chocolay rivers. Hatchery rainbow trout made up 15% of the Lake Superior catch and 10-44% of the catch in the tributaries. Hatchery brown trout made up 40% of the catch in Lake Superior and 4-50% in the tributaries. The contribution of hatchery lake trout decreased from 38% in 1984 to 18% in 1987.

Returns from hatchery planting to the sport fishery were less than 2% except for one plant of large yearling splake which was about 13%. Steelhead strains planted in the Chocolay River provided a better return (0.64-1.44%) than either steelhead or domestic rainbow trout planted in Lake Superior (0.08-0.52%). The returns of Siletz steelhead and coho salmon were about 1.4%. Brown trout returns were all less than 1%. These low returns prevented a conclusive assessment of the performance of domestic versus steelhead strains of rainbow trout and yearling versus fall-fingerling brown trout planted in Lake Superior. Straying and mortality both likely contributed to the poor return. Coho salmon planted in Lake Superior strayed as far as Lake Erie and were abundant in the sport fishery and at least one tributary of Lake Michigan. Michigan should (1) maintain an annual sport fishery creel survey, (2) protect and enhance spawning habitat and populations of native and naturalized trout and salmon, (3) cease planting hatchery trout and salmon, or (4) if some planting is judged necessary, apply documented strategies for improving return to the fishery.

PEDERSON, S. S. and G. H. RASMUSSEN. 2000. Survival of sea-water-adapted trout (*Salmo trutta*) ranched in a Danish Fjord. Fisheries Management and Ecology 7(4) : 295-303.

The effect of seawater adaptation on the survival of coastally released post-smolt trout (*Salmo trutta*) was investigated by release: (1) Directly (with no adaptation); (2) after retention in net pens in the sea for 29–131 days (delayed release); (3) after feeding with a high-salt diet (12–13.5% NaCl) for 4 weeks; and (4) after a combination of (2) and (3). In total, 17,640 trout (age = 1+, 1.5 and 2+ years; mean fork lengths = 18.2–25.6 cm) were released in 14 batches in the summer or autumn months of 1986–1989. All fish were of domesticated origin and Carlin tagged. Survival and instantaneous mortality rates (total and fishing mortality) were estimated from reported recaptures. Mortality rates were estimated for: (1) The post-smolt period; (2) the period until the legal size of capture (40 cm) was attained; and (3) for larger sea-trout. Release with a delay of 4 weeks gave an increased survival rate. A longer adaptation period did not increase survival. On average, survival was increased by 36%. Survival was not increased by high-salt diets. Until attainment of the legal size for capture, survival was 9.6% higher on average, with extremes as low as 1.7% and as high as 38% in individual batches.

PETERSSON, E. and T. JÄRVI. 2000. Both contest and scramble competition affect the growth performance of brown trout (*Salmo trutta*) parr of wild and of sea-ranched origins. Environmental Biology of Fishes 59 : 211-218.

The effect of contest and scramble competition on the growth performance of wild and sea-ranched juvenile (0+) brown trout (*Salmo trutta*) originating from the River Dalälven, Sweden was scrutinized. In a mirror image simulation (MIS) experiment, and in a 35,000-Litre stream-water aquarium the trout was studied for three weeks (20 individuals in each of four replicates). Activity in MIS was correlated with swimming activity in the stream-water aquarium. The MIS results could not be used for predicting any social behaviour patterns or the growth performance of a fish. No behavioural differences between the two strains were noted. However, the sea-ranched strain grew faster than the wild strain, both in regard to the RNA/DNA ratio and the weight-specific growth rate. Because the strains had the same genetic background and prior to the experiments were raised under similar hatchery conditions, the results of this study suggest that the sea-ranching process selects for faster juvenile growth in brown trout. The ultimate mechanisms underlying the faster growth by the domesticated strain probably involves both contest and scramble competition.

PIRHONEN, J. and L. FORSMAN. 1999. Can smolting and maturation of hatchery-reared brown trout (*Salmo trutta*) be affected by food deprivation during the first and second years of rearing? Aquaculture Research 30(8) : 611-620.

Smolting and maturation of 2+ brown trout (*Salmo trutta*) were evaluated after exposing the groups of trout to different feeding regimes during the summers at 0+ and 1+ ages. The hypothesis tested was based on the theory of smolting of a congeneric species, Atlantic salmon (*Salmo salar*) in which the physiological smolting decision is expected to be taken at the end of July or beginning of August. During the first summer, the growth of the trout was restricted in two groups out of four by low feeding frequency. During the second summer, food was totally withheld for 3 weeks in June–July (i.e. before the expected sensitive period), in August or not at all (control). The proportion of sexually mature males in November was 5.2% in the groups fasted during August, but somewhat lower in the groups fasted in June–July (average 2.3%) or in control fish (3%). The tendency for smolting was evaluated during the following spring in an artificial stream with the help of PIT-tag technology, which allowed monitoring of the movements of individually tagged trout. Seawater challenge tests were also carried out in April and June. Differences in osmoregulatory ability in seawater indicated that feeding treatments had a slight effect on the timing of smolting, but no differences were observed in movement behaviour between treatment groups. Mature and maturing males moved less at the peak migration time (mid-May) but more in October than immature fishes. These results suggest that the smolting decision in brown trout may be taken at a different time than in Atlantic salmon and that periodic poor growth conditions during the summer will not prevent smolting of trout during the following spring.

PIRHONEN, J., L. FORSMAN, A. SOIVIO and J. THORPE. 1998. Movements of hatchery-reared *Salmo trutta* during the smolting period, under experimental conditions. Aquaculture 168(1-4) : 27-40.

In an experimental flume tank, two-year-old, 20 cm *Salmo trutta* from both anadromous and freshwater resident stocks showed increased downstream movement, mostly diurnally, as the water temperature rose, from early May to early June, most intensely from 23 May-9 June, after which movement ceased. Water velocity was 20 cm sec^{-1}: At first the downstream speed of the fish was 7 cm sec^{-1}, suggesting that the fish were resisting displacement. At the most intense movement, the fish headed downstream, at only 4 cm sec^{-1} (0.2 body lengths sec^{-1}) faster than the water. Maturing males moved significantly less than did immature males and females. Individual fish that ate more, and that grew faster, moved less. The more that condition factors increased between February and mid-May, the less the fish moved. Taken together, these findings suggest that spring smolt emigration of trout, whether or not they belong to anadromous or freshwater resident stock, is principally by passive displacement.

POTEAUX, C., D. BEAUDOU and P. BERREBI. 1998. Temporal variations of genetic introgression in stocked brown trout populations. Journal of Fish Biology 53 : 701-713.

Allozymes were used to analyse the genetic impact of hatchery brown trout (*Salmo trutta*), morpha *fario* stocked in wild Mediterranian populations to gain better understanding of the mechanisms of introgression (regulation, elimination or homogenization). Analysis of the genetic structure of populations from the same river drainage basin but subjected to different incidences was performed in space and time (data on two generations and 2 years of sampling). Introgression is associated with high deficits of heterozygotes and linkage disequilibria. Genetic divergence according to age group was observed. These results may indicate selective forces acting against domesticated genes and limiting hybridization between the two forms.

POTEAUX, C., P. BERREBI, F. BERGOT and E. VIGNEUX. 1997. Genome integrity and trout stocking in the Mediterrenean basin. Bulletin Français de la Pêche et de la Pisciculture 344-345 : 309-322.

The stocking practices used for brown trout (*Salmo trutta*) in the south of France result in secondary contact and introgression between populations from two genetically differentiated forms of the same species: domesticated stocks that originate from the Atlantic form and the wild Mediterranean populations. This paper reviews the protein data for 44 Mediterranean samples examined in the laboratory, with an appraisal of introgression by the domesticated form and a description of the genetic consequences of stocking on the existing populations. The samples were collected from several French departments: Pyrenees Orientales (12 stations), Herault (5 stations), Vaucluse (2 stations), and Corsica (25 stations).

POTEAUX, C., F. BONHOMME and P. BERREBI. 1999. Microsatellite polymorphism and genetic impact of restocking Mediterranean brown trout (*Salmo trutta*). Heredity 82 : 645-653.

The genetic impact of restocking Mediterranean brown trout populations with hatchery stocks was investigated in the Orb River drainage (France), using genetic data from three microsatellite loci. We sampled two wild populations, the main river which is restocked each year and one of its tributaries which has not been restocked for 6 years. Each sample was divided into two age groups (juveniles/adults). Introgression of each native population by hatchery stocks was previously estimated using allele frequencies from two diagnostic protein-coding loci and one mtDNA haplotype. The genetic structure and allelic frequency at three microsatellite loci in native populations were compared with two hatchery samples belonging to stocks usually used for restocking this drainage. High levels of polymorphism (23–27 alleles per locus) were detected for two loci, whereas the third was less polymorphic. Polymorphism was significantly higher in the restocked population than in the now undisturbed population. Significant differences between age groups were observed in the main river, but not in its tributary. The introgression estimates using microsatellites were compared to those obtained from proteins and mtDNA. The different possible origins of alleles common to hatcheries and wild populations (homoplasy, ancestral polymorphism or introgression) are discussed.

POTEAUX, C., R. GUYOMARD and P. BERREBI. 2000. Single and joint gene segregation in intraspecific hybrids of brown trout (*Salmo trutta*) lineages. Aquaculture 186(1-2) : 1-12.

Brown trout (*Salmo trutta*) stocking practices in French Mediterranean rivers often result in artificial secondary contact and introgression between substantially differentiated genomes. Single and joint segregation at five protein and four microsatellite loci were analysed in two back-crosses between hybrid females (resulting from domestic x Mediterranean genitors) and hatchery males in order to test whether there is genetic incompatibility and selective phenomena between the genomes. Three crosses between hatchery genitors were performed and followed in the same time to measure and compare survival among back-cross (2) and hatchery (3) families. Only one of 23 single segregation tests

(LDH-5 for family 2) was significant with an excess of allele of the domestic origin in the F_1 hybrid. Out of 70 joint segregation tests, only six were significant. One segregation corresponded to "weak" associations involving one microsatellite locus (Strutta-24) and one enzyme (FBP-1). One case (Strutta-24 and Strutta-12) was clearly caused by differential maternal transmission of alleles. Even if the question of a breakdown of fitness is only addressed in the hatchery environment, these results showed the existence of events during meiosis, which have affected the allelic transmission for hybrids of the two genomes.

PRESTON, H. R. 1965. Culverson Creek reclamation. Federal Aid Project F-10-R-(1-6), Job No. 4, Final Report. West Virginia Department of Natural Resources. Charleston, West Virginia.

Culverson Creek, Breenbrier County was reclaimed by rotenone treatment in August 1960. The eliminated fish population was replaced with fingerling brown and brook trout.

The brown trout survival was sufficient to cancel put-and-take stockings the second year after reclamation. Mortality was the greatest during the first winter. The population density decreased at a greater rate during the first 18 months. Subsequent decrease was at a slower rate and at the same time, the rough fish population repopulated the stream rapidly. Some natural reproduction by the brown trout was noted.

The stream fish population had returned to pre-reclamation conditions by the fall of 1963. Annual plantings of catchable trout were stocked in 1963 and 1964. Angling efforts indicated better fishing early in the project, gradually declining, to pre-treatment status.

It is concluded that the reclamation provided more angling success for a short period at less cost as opposed to the put-and-take basis.

PYLE, A. B. and R. H. SOLDWEDEL. 1973. Investigations in the mortality of stocked trout in New Jersey streams. Miscellaneous Report No. 36. New Jersey Department of Environmental Protection. Trenton, New Jersey. 28 p.

Out of the eighteen streams employed in this study, six were found to be unsuitable for stocking with hatchery-reared trout until their temperatures increased to about 42° F after April 1^{st}. These six streams are located in central New Jersey and their chemical characteristics are considered to be largely responsible for the inability of brook, brown and rainbow trout from New Jersey's hatchery in Hackettstown to adjust and survive when stocked at colder temperatures. Toxicity is discounted as a factor because their waters maintain resident trout populations throughout the year.

Sulfate and aluminum concentration increases are associated with the colder water temperatures but they alone are not considered adequate to recognize other streams posing similar trout adjustment problems. Therefore, the "fingerprinting" of streams is suggested as an aid in dealing with this problem.

Mortality of the newly stocked trout is quite rapid, usually being complete in less than a week, with the order of decreasing susceptibility being rainbow trout, brown trout and brook trout.

QUÉBEC MINISTÈRE DU LOISIR, DE LA CHASSE ET DE LA PÊCHE. 1988,. Critères et pratiques d'ensemencement: Resumé et recommendations. Gouvernement du Québec, Ministère du Loisir, de la Chasse et de la Pêche, Direction Générale de la Ressource Faunique. Québec City, Québec.

When brown trout are stocked for supplementary purposes it is best to stock them at one year of age (13-18 cm) for a faster return to the fishery, at a rate of 125-250/ha. If fingerlings are to be planted, they should be stocked in the late fall (November) for maximum survival. Stocking for introductory purposes must be done according to the amount of competition present. With little or no competition fingerlings 8-10 cm may be stocked at a rate of 250-500/ha and in the presence of competitors fish between 13-18 cm should be stocked at a rate of 125-20/ha. When fishing pressure is high, catchables should be stocked in the springtime. Generally fish should be stocked at access points and when greater than 6.8 cm in length should be marked with fluorescent pigment for identification.

QUÉBEC MINISTÈRE DU LOISIR, DE LA CHASSE ET DE LA PÊCHE. 1988$_b$. Stocking guidelines for fish species other than anadromous Atlantic salmon. Ministère du Loisir, de la Chasse, et de la Pêche. Québec City, Québec.

Prior to permission to introduce brown trout into a waterbody is permitted a thorough assessment of potential impacts to the waterbody as well as surrounding watershed must be conducted. The introduction of this species into waters containing freshwater red charr, brook charr or lake charr is greatly discouraged. F_1 and F_2 hatchery strains may be stocked on an annual basis for at least two years. Another assessment must be conducted at this time to determine the consequences of the introduction.

Suitable lake habitat for brown trout varies and occurs in up to 6 m of water. The planting rate should not exceed 250,000 fry, 50,000 fingerlings or 25,000 age 1+ fish per waterbody. Planting rates are recommended with respect to the level of competition present in the lake:

- With little or no competition (maximum one species of cyprinidae): Fry or fingerlings should be planted at a rate of 1,500/ha and 300/ha, respectively.
- With moderate predation: Fingerlings or age 1+ should be planted at rates of 200/ha or 100/ha, respectively.
- With high levels of predation (warmwater communities in mesotrophic and oligotrophic lakes greater than 500 ha): Only age 1+ should be planted at a rate of 50/ha.

Suitable watercourses may also be stocked, with variations in the stocking rates:

- With little or no competition: Fry or fingerlings should be stocked at rates of 450/m (width) x km to a maximum of 9,000/km) and 90/m x km to a maximum of 1,800/km, respectively.
- With moderate competition: Fingerlings or age 1+ should be planted at rates of 60/m x km to a maximum of 1,200/km and 30/m x km to a maximum of 600/km, respectively.
- High competition: Only age 1+ should be stocked at a rate of 15/m x km to a maximum of 300/km.

QUILLET, E., F. KRIEG, A. HAPPE and B. CHAVASSUS. 1986. Study of possibilities of autumnal seawater transfer of brown trout fingerlings (*Salmo trutta*). Bulletin Français de la Pêche et de la Pisciculture 303(4) : 125-133.

Two ways of adaptation (direct or progressive) to 35 ppt salinity seawater were investigated on brown trout (*Salmo trutta*) ten months old for two different classes of mean weight (I:Wm = 40 g; S:Wm = 50 g). During the first three weeks after transfer into seawater, significant mortality (22%) was observed in "I" group transferred directly in seawater while good survival was exhibited by the three other groups (97%) (I and S with progressive transfer, S directly transferred). During the following period (5 months), survivals were good and similar in the four groups. At the end of this period, no difference in mean weight was detected between the two ways of transfer into seawater and mean weight was higher than for the control group in freshwater. So direct transfer, without negative effects on survival and growth, appears possible for individuals bigger than 40 g.

RADDUM, G. G., P. BRETTUM, D. MATZOW, J. P. NILSSEN, A. SKOV, T. SVEAELV and R. E. WRIGHT. 1986. Liming the acid Lake Hovvatn, Norway: A whole-ecosystem study. Water, Air, and Soil Pollution 31(3-4) : 721-763.

Hovvatn, a 1 km^2 chronically acidified lake in southernmost Norway, was treated with 200 tonnes of powdered limestone in March, 1981. An additional 40 tonnes were added to a 0.046 km^2 pond (Pollen) draining into Hovvatn. The lakes were stocked with brown trout (*Salmo trutta*) in June 1981 and in each subsequent year. At ice-out pH rose from 4.4 to 6.3 (Hovvatn) and 7.5 (Pollen), calcium and alkalinity increased, and total aluminum decreased by 120 mu g L^{-1}. None of the other major ions exhibited significant changes in concentration. Total organic carbon and phosphorus increased after liming. Hovvatn and Pollen were barren of fish prior to stocking. The stocked fish showed remarkably high growth rate during the first years. Liming apparently improved conditions for zoobenthos, enhancing the processing of fine detritus which in turn resulted in elevated levels of total organic carbon and phosphorus in the lakewaters during the first year after liming. The "oligotrophication" process typical of acid lakes was temporarily reversed by liming.

RAHKONEN, R. and P. KOSKI. 1997. Occurrence of cestode larvae in brown trout after stocking in a large regulated lake in northern Finland. Diseases of Aquatic Organisms 31(1) : 55-63.

The aim of this study was to obtain relevant information on larval cestode infection of brown trout (*Salmo trutta lacustris*) for fish stock management purposes in the large, regulated Lake Inari in northern Finland. Compensatory stockings of brown trout have been carried out annually since the mid 1970s. A total of 209 brown trout, which were stocked at the age of 3 years, were studied for larval cestodes in 1994 and 1995. *Diphyllobothrium dendriticum* was clearly dominant among the 4 cestode larval species found. The other species were *D. ditremum*, *Triaenophorus crassus* and *T. nodulosus*. After 1 summer in the lake the prevalence of *D. dendriticum* infection was 75% (abundance 5.3) and 46% (abundance 0.9) in 1994 and 1995, respectively. After 3 or more years in the lake (greater than or equal to 6+) every brown trout was infected with a mean number of about 130 larvae for both years. All organs in the body cavity were found to be infected. In addition, capsules containing *D. dendriticum* were found in muscles after the second summer in the lake and the prevalence of muscle infection was 73% (abundance 3.2) and 95% (abundance 7.1) in the oldest age group (greater than or equal to 6+) in 1994 and 1995, respectively. This has decreased the commercial value of the brown trout. A slight positive correlation between the number of *D. dendriticum* and the condition index (Fulton) of fish was found in each age group, although histological studies of heavily infected fish revealed severe chronic granulomatous peritonitis. Indications of elimination of individuals most heavily parasitized with *D. dendriticum* were not obtained for the present material. *D. dendriticum* was not found in the potential prey fishes of the brown trout studied in Lake Inari: vendace (*Coregonus albula*), whitefish (*Coregonus* sp.) and nine-spined stickleback (*Pungitius pungitius*).

RASMUSSEN, G. 1984. Liberation of trout (*Salmo trutta*) in Danish streams. *In* Documents presented at the Symposium on Stock Enhancement in the Management of Freshwater Fish. European Inland Fisheries Advisory Commission Technical Paper 42(1) : 164-177.

During the past century, pond-reared trout have been liberated into natural Danish fresh waters in order to compensate for decreasing salmonid production caused by the increasing deterioration of the physical environment. At the beginning of the century such stocking was performed in a very uncritical way without any regard to the biological requirements of the fish and no beneficial effect of these stockings has been demonstrated. From the mid 1930s, however, stocking of trout fry was systematized with regard to the habitat requirement of this developmental stage. Today, modern stocking schemes operate with fry, half-yearlings, yearlings, and two-year old fish (smolts). At present about 56% of Danish catchment areas are managed according to such modern schemes, according to which about 1,600,000 fry, 350,000 half-yearlings, 200,000 yearlings and 130,000 two-year old fish are liberated per annum.

The paper discusses the biological and technical principles for these schemes and gives an example of their effects on the trout stocks. The paper finally discusses the actual problems and outlines the work to be done in the future.

RASMUSSEN, G. and P. GEERTZ-HANSEN. 1998. Stocking of fish in Denmark. p. 14-21. *In* I. W. Cowx [ed.]. Stocking and Introduction of Fish. Fishing News Books, Blackwell Science, Ltd. MPG Books, Ltd. Bodmin, Cornwall, Great Britain.

Stocking of fish and crayfish in fresh and salt water has taken place in Denmark for more than 100 years, but with varying degrees of success. The aims were either to improve catch or to rehabilitate populations and species. Since 1991, non-commercial fishermen and anglers have paid an annual licence fee which is supplemented by the counties, private enterprises and fishery associations to support enhancement activities. This revenue is used for administration and information (4%), stock enhancement (82%) and research projects (14%). Stocking can only take place with the permission of the appropriate authorities and is performed according to specific guidelines on species, number and size/age of the stocked fish and stocking location. Nearly all stockings are with farmed fish, either F_1 offspring from wild fish, or from domesticated fish stocks, that have been held for several generations. The so-called 'principle of authenticity' is now being given high priority so genetic considerations are being increasingly incorporated into the management proposals.

The current brown trout stocking program in Denmark involves fry, half-yearlings, yearlings and sometimes older fish. When stocked into streams the following procedures are followed:

- To increase productivity the fish are stocked over as large an area as possible.
- The size of fish stocked must complement the summer depth of the stream.
- Carrying capacity dictates the number of fish to be stocked.

Stocking with 3-week-old fed-fry and yearlings occurs in April with maximum stocking rates of 200 and 20 fish/100 m^2, respectively. Half-yearlings are planted in October at a density no larger than 50 fish/100 m^2. Up to 5 older fish/100 m^2 can be stocked following the smolt period in June or July. One and two-year-old smolts are stocked at the mouths of rivers in March and April. These fish are stocked at a rate of up to 10 smolts/100 m^2 for stretches up to 6-7 m wide.

RATLEDGE, H. M. 1966. Impact of increasing fishing pressure upon wild and hatchery-reared trout populations. Proceedings of the Annual Conference of the Southeastern Game and Fish Commissioners 20 : 375-379.

Twelve years of trout stream management on the Standing Indian Wildlife Management Area in North Carolina has involved a fixed annual stocking of marked hatchery-reared trout (550 brook trout, 1,100 brown trout and 4,350 rainbow trout). A complete creel census has been mandatory on the Area streams so that the catch of both stocked and wild trout could be followed.

It was concluded from this study that: (1) Wild trout populations deteriorated after two consecutive years of 40 trips per acre per year; (2) hatchery-reared trout provided only a buffer to the destructive harvest of wild trout up to a point, then when the wild trout have been depleted the hatchery fish became dominant in the harvest; (3) up to that point, harvest of wild trout, not the harvest of the stocked trout, upheld the trout fishery; and (4) increased fishing pressure resulted in decreased average catch per hour, whereas, decreased pressure resulted in higher average catches.

RICHARDS, R. H. and A. D. PICKERING. 1978. Frequency and distribution patterns of *Saprolegnia* infection in wild and hatchery-reared brown trout (*Salmo trutta*) and char (*Salvelinus alpinus*). Journal of Fish Disease 1(1) : 69-82.

Fungal infection of sexually mature brown trout and char was associated with a particular type of Saprolegnia exhibiting a low degree of homothallic sexuality. Hatchery-reared brown trout were more severely infected (in terms of the % area of the body covered with the fungus) than were wild fish. The fins of hatchery-reared fish were particularly prone to Saprolegnia infection regardless of sex. In wild brown trout, a sexual difference in the pattern of infection was demonstrated. The flanks of the male fish appeared to be more prone to infection when compared with the female and there was greater susceptibility of the caudal and ventral fin of the female when compared with the male. Evidence is presented which suggests that the incidence of infection in mature male salmonid fish prior to spawning is significantly greater than in the females. This difference may not be apparent in spent fish after spawning. These findings are discussed in relation to the background concentration of fungal spores in the water, the behavioural characteristics of spawning fish and differences in epidermal structure.

RINTAMAEKI-KINNUNEN, P. and E. TELLERVO VALTONEN. 1977. Epizootiology of protozoans in farmed salmonids at northern latitudes. International Journal for Parasitology 27(1) : 89-99.

Protozoan ectoparasites were examined in a northern salmonid fish farm over a 10-year period, June 1984-May 1994, by the same researcher, with similar catching and sampling procedures throughout. Husbandry procedures remained constant during the study (e.g., fingerlings were kept in steel tanks and yearlings in both steel tanks and earth ponds). *Ichthyobodo necator*, *Chilodonella hexasticha* and *Ichthyophthirius multifiliis* infections were treated with formalin, salt and malachite green-formalin baths, respectively, whenever any parasites were found. Altogether 10,790 randomly sampled salmon (*Salmo salar*), sea trout (*S. trutta trutta*) and brown trout (*S. trutta lacustris*) were studied. Higher prevalences were found in yearlings than in fingerlings, except in *I. necator* infections, which were higher in fingerlings (e.g., 26% vs. 6% in sea trout). *C. hexasticha* occurred less often and was found most commonly on brown trout fingerlings. *Trichodina nigeria* occurred more often in salmon of both age groups and *Riboscyphidia arctic* in trout. The results show that the occurrence of protozoan parasites in a fish farm is predictable and is influenced by the fish species, the age group of the fish, the season and the tank type. Parasite burden increased up to 7 species per brown trout (e.g., when fish were studied from hatching until stocking at the age of 2 years).

RUHLE, C. 1983. Sea trout problems in Constance Lake and its tributaries. Schriftenreihe Umwelt Fischerei 41 : 91-105.

Stocking operations in Constance Lake with sea trout (*Salmo trutta lacustris*) led to the development of a trout population without imprinting for spawning migrations. Consequently autochthonous spawners were no longer available. The gap was filled by rainbow trout. In order to rebuild a new anadromous trout population, starting with the few specimens, which had been caught near the weir of Reichenau in 1980, not only structural alterations but also adjustment of season- and size-limit-regulations to the reproduction of sea trout is necessary. Artificial imprinting is taken into consideration.

RYMAN, N. and G. STÅHL. 1980. Genetic changes in hatchery stocks of brown trout (*Salmo trutta*). Canadian Journal of Fisheries and Aquatic Sciences 37 : 82-87.

Preservation of the genetic characteristic of a population is one of the primary objectives of many fish stocking programs. Using starch gel electrophoresis we have tested for temporal gene frequency stability at two polymorphic loci coding for a α-glycerophosphate dehydrogenase and creatine phosphokinase. Three Swedish hatchery stocks of brown trout (*Salmo trutta*) and field samples from natural populations corresponding to two of these stocks were analyzed. Highly significant allele frequency changes at both loci indicated considerable lack of intra-stock genetic homogeneity. In the light of these findings we emphasize the importance of using large numbers of actual as well as effective parents to avoid inadvertent genetic changes and inbreeding. No stock should be founded or perpetuated using less than approximately 30 parents of the least numerous sex in any generation.

SALTVEIT, S. J. 1993. Abundance of juvenile Atlantic salmon and brown trout in relation to stocking and natural reproduction in the River Laerdalselva, western Norway. North American Journal of Fisheries Management 13 : 277-283.

Since the regulation of the river Laerdalselva in 1974 many juvenile Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) have been stocked above the natural reach of anadromous fishes to compensate for possible loss in Atlantic salmon production. The parental material for the stocking was obtained from the lower parts of the river. In 1988, the numbers of fish stocked were drastically reduced. The density of Atlantic salmon (all year classes) was 75-80% less in years of light stocking than in years of intensive stocking. For Atlantic salmon, a strongly significant ($P>0.001$) correlation was found between the numbers of young of year parr (age 0 fish) stocked in the river and the corresponding density of age 0 fish. The reduction in Atlantic salmon density occurred even though the fish ladders allowed fish migration to the spawning grounds. However, few of the Atlantic salmon moving up the fish ladders were females, so natural recruitment was severely limited. The last year sea-run brown trout were stocked was 1987. Therefore, the density of brown trout now results solely from natural recruitment from the anadromous and resident populations in the river.

SAURA, A., J. MIKKOLA and E. IKONEN. 1990. Re-introduction of salmon (*Salmo salar*) and sea trout (*Salmo trutta*) to the Vantaanjoki River, Finland. p. 127-136. *In* W. L. T. van Densen, B. Steinmetz and R. H. Hughes [eds.]. Management of Freshwater Fisheries. Proceedings of a Symposium by European Inland Fisheries Advisory Commission, May 31-June 3, 1988, Göteborg, Sweden.

The Vantaanjoki River flowing into the Gulf of Finland supported a sea trout run until 1872, when the mouth of the river was dammed. In the 1940s, the river became heavily loaded with municipal and industrial waste waters. The Vantaanjoki was also used as a source of raw water for the city of Helsinki and, during dry summers, the water intake from the river was so large that the flow to the sea was almost negligible. Since then the effectiveness of the waste water treatment has increased and the water intake for Helsinki has been changed to another watercourse. Because of the improvement in the river, attempts were made to re-introduce sea trout in 1980. Releases of sea trout and salmon fry and fingerlings, were successful. Stocking at the rate of 300-700 sea trout alevins per 100 m^2 yielded about 30 1-year old parr per 100 m^2. The optimal stocking density for salmon fry is 600-800 individuals per 100 m^2. Being strong competitors, salmon and trout may replace other species in the nursery areas. The size of the nursery areas for sea trout and salmon in the River Vantaanjoki is about 14 hectares. The growth rate is fast and the smolt stage is reached in 2 years. This area could produce about 45,000 sea trout or salmon smolts per year. For this number, releases of 0.5-1.1 million alevins would be needed. Numerous brooks flowing to this river might also be suitable nursery grounds for sea trout and salmon, and smolt production could thus be increased. This scale of smolt production does not support a sufficiently large spawning run to the river to allow natural reproduction and fishing in the river. Fishing of these two species is so intense in the Baltic, that about 90% of the catch is taken in the sea. The target is to make a sport fishery possible in the Vantaanjoki area. As the potential smolt production is too small for this purpose, releases of hatchery-reared sea trout and salmon smolts are also needed in the river. If the target spawning run is 1,000-1,500 sea trout and salmon, 1.5 million fingerlings must be released yearly in the nursery areas, and 60,000 sea trout smolts and 150,000 salmon smolts. However, regulation of the fishing effort in the sea would reduce the need for releases.

SCHEERER, P. D., G. H. THORGAARD and J. E. SEEB. 1987. Performance and developmental stability of triploid tiger trout (brown trout female x brook trout male). Transactions of the American Fisheries Society 116 : 92-97.

Triploid fish hybrids frequently survive better than diploid hybrids. Tiger trout are a sterile hybrid between female brown trout (*Salmo trutta*) and male brook trout (*Salvelinus fontinalis*); they have a poor early survival rate but a good growth rate. We produced triploid tiger trout by heat shock treatments of fertilized eggs and examined their survival and growth under hatchery conditions. Triploid tiger trout survived better to the initiation of feeding (34%) than did diploid tiger trout (5%) but had lower survival than brown trout (70%). Triploid tiger trout had similar survival to and better growth than brown trout when the two groups were reared together for 239 days after the initiation of feeding. Analysis of the asymmetry of bilateral meristic traits indicated higher developmental stability in the triploid hybrids than in the diploid hybrids. Expression of both parental alleles of enzyme loci, determined by protein electrophoresis, confirmed the hybrid nature of the offspring. Triploid hybrids could be distinguished reliably from diploid hybrids by differences in relative expression of maternal and paternal alleles at some, but not all, loci. Triploid tiger trout appear to be a vigorous hybrid that could be of particular value in situations where all-sterile trout populations are desired for stocking.

SCHLUNTZ, E. C., J. J. BENDER, G. H. LEONARD and E. A. MACHOUSKI. 1999. Trout research and management in Connecticut lakes and ponds. Federal Aid Project F-57-R-16, Job No. 1, Project C, Final Report. Connecticut Department of Environmental Protection. Hartford, Connecticut. 74 p.

Our objectives were to: (1) Improve fishing for large holdover brown trout in lakes with suitable water quality and forage while maintaining put-and-take trout fisheries at existing levels; (2) evaluate 12-16 inch slot length limit regulations on Crystal Lake, Highland Lake and Quonnipaug Lake as a method to increase numbers of holdover trout; (3) evaluate growth, survival, and catchability of different strains of brown trout; (4) evaluate a 14-22 inch slot length limit implemented at East Twin Lake to maximize numbers of large brown trout and reduce alewife abundance by predation, thereby allowing re-establishment of a kokanee salmon fishery; and (5) restore the kokanee salmon population in East Twin Lake so that the lake supports a fishery and can be used as a source of broodstock.

SCHOLZ, A. T., J. C. COOPER, R. M. HORRALL and A. D. HASLER. 1978. Homing of morpholine-imprinted brown trout (*Salmo trutta*). National Oceanic and Atmospheric Administration Fishery Bulletin 76(1) : 293-295.

Homing in order to spawn has been documented for sea-run brown trout. To test the relation between homing and spawning area 1.5 year old hatchery fish were exposed to morpholine for 40 days and then stocked into Lake Michigan. A stream was simultaneously scented with morpholine. Results showed that 17.7% of the fish were recaptured at the scented stream, in contrast to 1.0% and 4.7% of control fish, demonstrating that fish exposed to the chemical returned to the scented stream in larger numbers than those who weren't. To locate this scented stream the fish were able to search a total distance of at least 13 km.

SCHUCK, H. A. and O. R. KINGSBURY. 1948. Survival and growth of fingerling brown trout (*Salmo fario*) reared under different hatchery conditions and planted in fast and slow water. Transactions of the American Fisheries Society 75 : 147-156.

Data obtained on Crystal Creek, New York, relative to the effectiveness of planting brown trout in slow and fast water are presented. Of three plantings of fingerlings made throughout the length of the stream, annual electrical inventories showed a significantly greater number of fish present in fast-water sections than in slow-water sections. Of the June 1940 planting, 20.2 trout per fast-water section and 10.1 trout per slow-water section were found after three months; of the September 1941 planting, 6.8 per fast-water section and 2.6 per slow-water section were recovered after one year; of the October 1940 planting, 1.0 per fast-water section and 0.62 per slow-water section were taken after one year.

In other experiments over a summer period only, where fish were planted in screened-off areas of fast or slow water, inventories after short periods of time also showed the survival to be greater in fast water. Of two plantings in each water type, after four weeks there were 2.2 times as many fish surviving in the fast water as in the slow water. Growth rates of planted brown trout in both series of experiments were also greater in fast water.

One experiment was designed to measure the effect of rearing trout in the hatcheries on a diet composed of meat and dry foods as contrasted to a diet of straight meat. The criteria employed were relative survival and growth rates after planting of trout reared under these conditions. No differences in the survival or growth associated with hatchery diets could be found. The amount of data available for this test was limited, however.

Differences in survival and growth of successive plantings made in the same sections of stream indicate the variability of stocking results and suggest the necessity of evaluating further the effects of various hatchery procedures and stocking methods upon the success of plantings.

SCHULZ, U. H. 1999. Downstream migration of European lake trout (*Salmo trutta lacustris*) and resident brown trout (*Salmo trutta fario*) progeny in a Lake Constance affluent river. Fisheries Management and Ecology 6(3) : 187-194.

The local migratory behaviour of lake trout (*Salmo trutta lacustris*) and resident brown trout (*S. trutta fario*) progeny from an inflowing stream of Lake Constance was compared. No differences were detected with respect to emigration rate (3.5% and 4.2% for lake trout and resident trout, respectively), rate of residency (6.8% and 8.2% for lake trout and resident trout, respectively) and rate of survival (12.3% and 12.1% for lake trout and resident trout, respectively) one year after stocking. Some of the resident brown trout offspring became migrants and vice versa. The results indicate that the progeny of riverine brown trout contribute considerable numbers to lake trout stock.

SCHUMACHER, R. E. 1954. Dusche Creek tagged trout study - 1954. Investigational Report No. 160. Division of Game and Fish, Bureau of Fisheries, Minnesota Department of Conservation. St. Paul, Minnesota. 6 p. + appendices.

A trout creel census was carried out on Dusche Creek tributary to the Root River in Fillmore County during the trout season, May 1, 1954 to September 15, 1954. The project was planned for two years therefore this is a preliminary progress report.

On April 27, 564 tagged brown trout yearlings averaging 4.44 per pound and 561 tagged rainbow trout yearlings averaging 4.56 per pound were stocked in Dusche Creek. A second stocking of 534 tagged brown trout and 523 tagged rainbow trout was made on May 27. All tagged trout were marked with a #3 Monel metal strap tag fastened to the right opercular flap.

The week following the closure of the angling season a population estimate was made of the entire census area with a 220 volt, 10 amperes, direct current generator and an electric seine.

With the exception of the first two weekends of heavy fishing a single creel census clerk contacted 83.7% of the estimated maximum possible fisherman trips. During the first two weekends three additional clerks assisted to make the census as complete as possible.

Two thousand and seventy fisherman trips were recorded with a total 6,264 man-hours of fishing effort. The total estimated number of fisherman trips was 2,400 spending an estimated 7,377 man-hours of fishing.

The total recorded rainbow trout catch was 889 trout of which 234 bore tags. The observed fishing success was 0.43 rainbow trout per fisherman trip or 0.14 rainbow trout per man-hour. The total recorded brown trout catch was 1,768 trout of which 259 bore tags. The observed fishing success was 0.43 brown trout per fisherman trip or 0.28 brown trout per man-hour. The total number of trout caught including 187 brook trout was 2,844 trout giving a fishing success ratio of 1.37 trout per trip or 0.45 trout per man-hour.

Comparisons of the relative catchability of brown and rainbow trout are inconclusive.

The tagged brown trout stocked and caught during the season amounted to 23.6% and 21.6% of the tagged rainbow stocked were caught during the angling season. The effect of a large population of catchable sized trout escaped from the state hatchery must have had an incalculable effect on the tagged trout stocked thus rendering the conclusiveness of the relative catchability useless.

The trout population present after the closure of the angling season as determined by the electric seine showed only 16 tagged brown trout and 4 tagged rainbow trout remaining in the stream.

SCHUMACHER, R. E. 1958. Dusche Creek creel census – Population study for 1954-1955. Fisheries Investigational Report No. 176. Minnesota Fish and Game Investigations. St. Paul, Minnesota. 25 p.

The feasibility of providing angling with rainbow trout stocked in streams from which they could emigrate was tested on Dusche Creek in southeastern Minnesota. It was sought to determine whether yearling rainbows stocked in a marginal but heavily fished trout stream would be caught in sufficient numbers prior to this migration to warrant their use as a substitute for the less readily caught brown trout in a portion of the stocking quota. Observations were made on the return to anglers of two different years of stocking, including both fall and spring stocked brown and rainbow trout. All stocked fish were suitably marked for later identification.

Anglers in 1954 took 23.6% of the brown and 21.6% of the rainbows stocked in the spring of that year. In 1955, they caught 51.4% of the brown and 46.9% of the rainbow stocked in the fall of 1954. This was 77.4 and 100% respectively of the brown and rainbow trout left in the stream at the beginning of the season following the fall plant. Of the fish stocked in the spring of 1955, 68.3% of the browns and 82.9% of the rainbows were caught.

Population estimates derived by electric seine in the spring revealed an over-winter survival of fall stocked 18 month old trout to be 70% of the browns and 55.5% of the rainbows. Eighty-five percent of the fall stocked browns and 84% of the fall stocked rainbows that were caught the next season were taken in the first week of the season. Spring stocked brown and rainbows did not yield 85% of the total harvest until 31 and 27 days, respectively, after the season opened.

SCULLION, J. and R. W. EDWARDS. 1979. The movement of hatchery-reared rainbow and brown trout in a polluted river in the South Wales coalfield. Journal of Fish Biology 14 : 173-178.

Hatchery-reared rainbow and brown trout (length 20 cm) were released in March 1974 and April 1975, respectively, into the Taff Bargoed, a small river in south Wales, polluted by coal and wastes and containing a low resident population of brown trout. From subsequent electrofishing surveys and catch returns from anglers, extensive downstream movements occurred in both species. About 50% had either been caught or had moved out of the river, a distance of about 5 km, after two weeks and after two months only some 10% remained. Within the fishing season it was estimated that 3% and 22% of brown and rainbow trout respectively were caught.

SHELBY, W. H. 1917. History of the introduction of food and game fishes into the waters of California. California Fish and Game 3 : 3-12.

Since the 1800s numerous introductions of freshwater fish species have been made in order to supplement the resident species for fishing purposes. Although, previously foreign percids and cyprinids have been introduced, salmonids are generally more efficient at providing a sport-fishery basis.

In February, 1894, 20,000 eggs of the Loch Leven or Scotch Lake brown trout (*Salmo trutta levenensis*) were sent to the California commission from the stock ponds of the United States Government at Northville, Michigan. They were hatched at Sisson Hatchery, and the fry deposited in the hatchery ponds, where they thrived. The stock has been retained in the Sisson Hatchery ponds ever since, where they have been propagated successfully, and thousands of the fry are shipped each year for distribution in the public waters of the state.

The Loch Leven and the German brown trout are closely allied and appear to be but different varieties of the same species. They are somewhat different in their habits, but do equally well in the clear, cold lakes and streams of the Sierras, as well as in the region around Mount Shasta. The two varieties have been crossed at the Sisson hatchery and have produced a strong, game fish.

In 1895, 135,000 Von Behr or German brown trout eggs (*Salmo fario*) were hatched at the Sisson Hatchery. Several thousand fry were placed in the ponds to be raised for breeders and the remainder were distributed in a number of the lakes and streams of the high Sierras. Previous to this the federal government had made several plants in the state.

SHETTER, D. S. 1944. Further results from spring and fall plantings of legal, legal-sized, hatchery-reared trout in streams and lakes of Michigan. Transactions of the American Fisheries Society 74 : 35-58.

Further tagging experiments in Michigan with spring and fall plantings of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdneri irideus*) from which recoveries were made during the 1942 trout season confirmed the conclusion that spring release of adult hatchery-reared brook trout and rainbow trout is more desirable than the fall planting of fish of similar size. In some instances fall stocking of brown trout may furnish as good fishing in the following seasons as does spring planting.

Recoveries of planted fish past the first season of availability ranged from 0.0 to 2.5% in the second season and 0.0 to 0.5% in the third season.

In either spring or fall planting of legal-sized fish, no advantage was gained by scattering the fish widely over the stream areas stocked.

Eighty-five percent or more of the planted trout recovered were caught within 10 miles of the point of release, regardless of the season or the method of planting. Brown trout moved the least and rainbow trout the most. About one-fourth of the brook trout tended to move 3 to 10 miles downstream, and the majority of the remainder were caught within 3 miles of the locality of release. More rainbow trout than any other species were recaptured 10 or more miles from the point of release.

Fall plantings of adult brook trout in lakes were recovered at the rate of 56.7% (range, 13.0 to 88.1%). Unfortunately, a small percentage of the anglers removed an average of 89.4% of the total catch during the opening weeks of trout season. The average recovery from two spring plantings of brook trout in East Fish Lake in Michigan was 68.5%.

A brief review of literature substantiates the conclusions reached as a result of the Michigan experiments. Differences in experimental procedure are pointed out, and some reasons are offered for the failure of fish planted in streams in the fall to survive the winter season.

SHETTER, D. S. 1962. Recoveries by anglers of legal sized trout stocked during different seasons of the year in Michigan streams. Transactions of the American Fisheries Society 91: 145-150.

Four experiments with marked, legal-sized, hatchery-reared brown and rainbow trout were conducted on portions of five Michigan trout streams to determine which season of release would yield the greatest return to the angler. Equal numbers of tagged or fin clipped fish were planted in the fall after the close of the trout season and in the spring before the trout season opened. In two experiments, larger number of fish were also released during the fishing season; May, June, and July. In three of the experiments, angler returns were obtained by voluntary reports and by partial creel census conducted during the first season that marked fish were present. In the fourth experiment, all recoveries were reported voluntarily. Almost 63,000 fish were planted and recaptures of 1,173 brown trout and 2,307 rainbow trout were reported. In six tests with rainbow trout and four tests with brown trout, spring planting yielded significantly higher returns than did fall planting. In two tests with brown trout, spring planting yielded higher returns but its superiority over fall planting was not statistically significant.

SHETTER, D. S. and A. S. HAZZARD. 1940. Results from plantings of marked trout of legal size in streams and lakes of Michigan. Transactions of the American Fisheries Society 70 : 446-468.

Intensive creel censuses served as the chief basis for estimates of the effectiveness of plantings of marked legal-sized brook trout, brown trout and rainbow trout at various seasons over a period from 1 to 3 years in sections of five public streams and in two private streams. Similar data are presented for plantings of rainbow trout in five lakes. Returns from fall planting in streams never exceeded 5.3%; spring and open-season plantings in spring resulted in the recovery by anglers of from 4.9 to 61.9% of the fish released. Fall plantings of rainbow trout in lakes yielded returns up to 66%. Plantings of from 100 to 160 trout per mile of stream averaging 50 feet in width yielded higher percentage returns than did plantings of larger numbers of fish, benefited relatively more anglers and did not stimulate the catch of native fish. The increase in the catch-per-hour and the percentage of hatchery fish in the total catch appeared to be inversely proportional to the density of the native population of the species stocked and directly proportional to the number of fish planted. The percentage of the total catch contributed by plantings of moderate numbers of trout in the spring or during the season varied from 1.8 to 30.4. It is concluded that in northern Michigan streams, major dependence for good fishing must be placed on the native or "wild" stock. Rainbow trout and brown trout were caught for at least eight weeks following planting, although the majority was removed by the end of the 4 weeks; few if any brook trout were taken after 4 weeks. Very few planted trout survived one or more winters even in private streams not subject to intense angling. Most of the trout were taken within 5 miles of the point of release and usually downstream; of the three species, rainbow trout migrated most extensively. From 5.7 to 20.6% of the fisherman-day records showed the capture of marked trout. Apparently as many anglers benefited from "spot" plantings as from wider distribution by boat. Control experiments proved that jaw-tagging and fin-clipping provided effective methods of tracing fish during the period of investigation and that mortality and the effect on growth of either method were negligible.

SHETTER, D. S., W. C. LATTA, M. G. GALBRAITH, J. W. MERNA and G. P. COOPER. 1964. Studies on fishing regulation and productivity of trout waters: Returns on hatchery trout in Michigan. Institute for Fisheries Research Report No. 1691. Michigan Department of Conservation. Lansing, Michigan. 34 p.

SKAALA, O., K. E. JORSTAD and R. BORGSTRON. 1996. Genetic impact of two wild brown trout (*Salmo trutta*) populations after release of non-indigenous hatchery spawners. Canadian Journal of Fisheries and Aquatic Sciences 53(9) : 2027-2035.

A genetically marked strain of brown trout (*Salmo trutta*) was employed to study the genetic impact from non-indigenous hatchery fish on wild stocks. The hatchery spawners were released in autumn 1989 into the spawning localities of two wild trout stocks in River Óyreselv, Norway. The F_1 generation was sampled and genotyped at the 0+, 1+, and 2+ stages. Juveniles carrying the genetic markers were found in both localities, proving that the introduced spawners had spawned among themselves and with the wild stocks. The genetic contribution from the hatchery fish was estimated at 19.2 and 16.3% at the 0+ stage in the two wild stocks. Estimates of survival rates of 0+ trout revealed that survival was nearly three times higher in wild trout than in hybrids of wild and introduced trout, possibly because of a difference between introduced and wild stocks in size of eggs and alevins. The frequency of the marker alleles in the F_1 generation declined during the 2-year observation period.

SKROCHWSKA, S. 1969. Migrations of the sea-trout (*Salmo trutta*), brown trout (*Salmo trutta fario*) and their crosses. Polskie Archiwum Hydrobiologii 16(29) : 125-140.

In order to investigate whether the progeny of sea-trout living exclusively in freshwater show a migration instinct, smolt-sized sea-trout of F_2-F_4 pond generation were tagged and released into the River Raba. They were obtained from the artificial spawning of sea-trout caught in the Rivers Dunajec and Rudawa. Besides the "pond" sea-trout, young F_1 sea trout, brown trout, and their crosses were liberated. The fish were reared in ponds. The results obtained indicate that two-thirds of the fish did not leave the rivers before recapture and one-third descended from the Raba for the sea. The recapture of migrating fish from the spring stockings were twice as high as those from the autumn stocking. Mature male parr recaptured after descent from the Raba were ten times less numerous than the immature specimens. The recoveries of mature females were thirteen times as high as those of males.

SKURDAL, J., O. HEGGE and T. HESTHAGEN. 1989. Exploitation rate, survival and movements of brown trout (*Salmo trutta*) stocked at takeable size in the regulated rivers Lågen and Otta, southern Norway. Regulated Rivers: Research and Management 3 : 247-253.

Takeable size (age 4+, length 27-67 cm), hatchery-reared brown trout (*Salmo trutta*) were released into the rivers Lagen and Otta and the Glomma River System, southern Norway, in May-July 1981 and 1983-87. The brown trout released in May gave significantly lower recapture rates compared to those released in June/July (i.e. 22.8% compared to 41.6-58.0%, respectively). Mean exploitation rate and survival rates ranged from 0.23-0.58 and 0.02-0.14, respectively. Within 15 days after release 50% were recaptured, and 90% were caught within 67 days. The frequency of recapture increased significantly with fish length in the length interval 30-45 cm, but decreased for bigger fish. The stocked brown trout were stationary and 95% of the recaptures were caught less than 1 km from the site of release. Frequency of recapture ranged from 19.2

to 54.7% in six experiments with takeable sized brown trout in different tributaries of the Glomma River System, and the variations are probably mainly due to differences in fishing pressure.

SMITH, L. L., Jr. 1948. Creel census of South Branch of Whitewter River, Winona County – May 1 and 2, 1948. Division of Entomology and Economic Zoology, University of Minnesota. St. Paul, Minnesota. 11 p.

The opening two days of the 1949 trout season on South Branch of the Whitewater River were marked by excellent weather and stream conditions but much poorer fishing success than usual. Fishermen took trout at an average rate of 0.32 fish per hour and only 47.9% of the anglers caught any fish. Brown trout predominated in the catch almost to the exclusion of other species, and marked fish comprised 10.2% of the total catch.

Rough estimates on survival of marked fingerlings planted in 1946 indicate that between 5 and 8% lived to enter the 1948 season. For the purpose of management plans it will be safest to assume the smaller figure since the larger can be considered a maximum. Although the cost of catchable fish is approximately three times that of fingerlings, the survival rates of catchable fish to the creel is 5 to 6 times greater. It would, therefore, seem more economical to continue catchable-sized fish planting rather than fingerling planting in streams similar to the South Branch of the Whitewater. Condition of fish taken from the streams was good but average size suggested that most fish were spring plants.

Better fishing on the South Branch will come from habitat maintenance and improvement rather than from much larger plantings of fish. Recent deterioration caused by logging has resulted in fewer and poorer pools and generally poorer conditions for both survival and fishing.

SMITH, L. L., Jr. and B. S. SMITH. 1943. Survival of seven to ten inch planted trout in two Minnesota streams. Transactions of the American Fisheries Society 73 : 108-116.

Jaw-tagged 7 to 10 inch brook trout and brown trout were placed in two Minnesota streams to determine their survival. A creel census conducted on Duschee Creek showed that trout were returned at the rate of 1.49 and 1.55 fish-per-hour in succeeding seasons. Brown trout planted in this stream in the fall and spring yielded returns of 21.7% and 28%, respectively, but no brook trout and only 2.0% of brown trout planted in the summer were caught the following year. Planted trout contributed 8.8% and 22.7% of the total catch in successive seasons.

Catchable-sized brown trout and brook trout planted in the Knife River in the fall and in the spring showed a total return of 1.9% from fall planting and 14.1% from spring planting. Two and four-tenths percent of the brook trout and 8.6% of the brown trout planted in the spring were recaptured. The contribution of the planted fish to the total catch in the Knife River was 23.0%. The studies indicated that in the streams studied fall planted brown trout may have survival comparable to that of spring planted fish, that the majority of planted fish recovered are taken the first 3 to 4 weeks of the season, and that planted fish contribute only a minor portion of the total catch.

SMITH, H. M. 1986. A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific United States. Bulletin of the United States Fisheries Commission 15 : 379-472.

SMITH, N. W. 1991. Fish stocking in the southwestern region, 1974-1989: An historical review and rationalization. Ontario Ministry of Natural Resources. Toronto, Ontario. 80 p.

In the Owen Sound District brown trout have been stocked for rehabilitative, supplementary, introductory and put-and-delayed-take purposes. Stocking the local rivers provides a fishery in Lake Huron near Kincardine. Brown trout are stocked in this area to diversify the fishery. It is unknown whether or not the populations are establishing themselves or if they are relying entirely on stocking. In addition to Ministry stocking the Sydenham Sportsmen's Association has also been trying to enhance a brown trout fishery in the area of Owen Sound. Between 1983 and 1989, 221,500 fish were stocked. Until 1985 the stocking consisted only of fry, and later excluded fry and only fingerlings and yearlings were stocked.

Between 1974 and 1989, approximately 47,800 brown trout were stocked by the Ministry of Natural Resources in the Simcoe District. Originally wild eggs were used in hatcheries so that the fry stage could then be stocked back into the waters. This practice was discontinued in 1977 due to concern over the possibility of disease transmission through the wild eggs. The same year adult brown trout were transferred within the district. Eggs are currently cultured in incubation boxes and all stocks used are local to ensure higher degrees of survival. Stocking has continued as a CFIP project since 1985.

SOSIAK, A. J. 1982. Buoyancy comparisons between juvenile Atlantic salmon and brown trout of wild and hatchery origin. Transactions of the American Fisheries Society 111 : 307-311.

Buoyancies of juvenile Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) were examined as differences may influence stream distribution and feeding habits of these species. Among age 0 and age 1 fish living and tested in moving water, hatchery-reared Atlantic salmon were less buoyant than brown trout. After four days in still water, Atlantic salmon had increased their buoyancy to the point that age 0 (but not age 1) fish were as buoyant as comparably aged brown trout. In streams, low buoyancy would help Atlantic salmon to stay near the substratum where water velocity is less. This would enable them to inhabit areas of higher velocity than brown trout. Body density, and swim bladder length and weight did not appear related to buoyancy differences between species. Among brown trout, hatchery fish were more buoyant than wild fish possibly due to differing diets (especially lipid contents) or to genetic differences.

STALEY, J. 1966. Brown trout. p. 233-242. *In* A. Calhoun [ed.]. Inland Fisheries Management. California Department of Fish and Game. Sacramento, California.

The brown trout is native to Europe and first entered North America over one hundred years ago. The Loch Leven/Scotch strain originates in Scotland, while the Von Behr/German strain is from central Europe. In 1884, eggs of the Loch Leven strain were sent to California, with the arrival of the German strain the next year. Although the two strains were separate for many years, they eventually became mixed in the hatcheries and the two are now indistinguishable. Most recently in California the use of the Convict Lake strain (non-domesticated), the Mount Whitney strain (domesticated) and the Massachusetts and New Jersey strains (highly domesticated) has been widespread. Studies conducted on Lower Sardine Lake have demonstrated that a greater number of the stocked Massachusetts strain mature after their first year than do the Mt. Whitney strain.

In 1941, California drastically reduced the number of brown trout which were stocked into state lakes. This species is considered difficult to rear when compared with others such as the rainbow trout. Lower than expected returns of stocked fish caused a review of brown trout management policies. It was decided that larger fish were worth stocking in that they provided a quicker return to the angler.

Demands to stock brown trout in streams often stems from the desire of experienced anglers to catch trophy fish. Brown trout withstand competition from other trout and angling pressure so well that they commonly grow to large sizes. Yet, brown trout are generally less suitable for stocking in California waters than rainbow trout. It is unprofitable to stock brown trout fingerlings routinely in streams.

In most lakes brown trout should be used with caution. Large fish tend to accumulate in substantial numbers and become voracious predators which are rarely caught by anglers. Browns might be considered for stocking in lakes which are overpopulated with brook trout, especially if the lakes are shallow and species eradication through chemicals isn't feasible.

STANFIELD, L. W. 1987. A summary of the 1986/1987 fish and wildlife special programs in the Owen Sound district. Ontario Ministry of Natural Resources. Owen Sound, Ontario. 74 p.

In order to enhance the brown trout fishery in Owen Sound Bay the Sydenham Sportsmen's Association reared eggs to the fall fingerling and yearling size prior to releasing them in the river. In total 61,658 fall fingerlings were released in the fall of 1986 and a total of 1,089 fish were held over winter. A total of 59,037 eggs were collected from the Sydenham River to be reared and released in 1988.

Attempts were made by the Ontario Fishermen Magazine and Sydenham Sportsmen's Association to grow brown trout and chinook salmon at accelerated rates in warm water. It was found that water temperatures were unacceptably high and 758 of 9,600 brown trout died of temperature-related stress prior to stocking. This project will be discontinued.

STEFANIK, E. L. and M. B. SANDHEINRICH. 1999. Differences in spawning and emergence phenology between stocked and wild populations of brown trout in southwestern Wisconsin streams. North American Journal of Fisheries Management 19(4) : 1112-1116.

We compared the timing of spawning and emergence between stocked and wild populations of brown trout (*Salmo trutta*) in nine streams in southwestern Wisconsin during fall 1995 and spring 1996. Stocked populations of brown trout had a median date of redd formation 10 days before wild trout, 75% of redds being constructed 12 days before wild trout. On average, alevins of stocked trout emerged 17 days earlier from redds constructed on the median date of redd formation than did alevins of wild trout. Compared to wild trout, alevins of stocked trout emerged 13 days earlier from redds made on the date of 75% redd formation. Earlier fall spawning and the accompanying earlier spring emergence of alevins may influence reproductive success of the population. Timing of spawning should be carefully considered when selecting brown trout of wild or domestic origin to establish reproducing populations within streams.

STENSON, J. A. E. and J.-E. SVENSSON. 1994. Manipulations of planktivore fauna and development of crustacean zooplankton after restoration of the acidified Lake Gaardsjoen. Archiv fur Hydrobiologie 131(1) : 1-23.

Major changes occurred in the crustacean community both after liming of the originally acidified and fishless Lake Gaardsjoen and after benthivorous brown trout (*Salmo trutta*) stocking four seasons later. Species diversity increased after liming, but decreased after fish introduction. The dominant copepod, *Eudiaptomus gracilis*, was relatively unaffected by the manipulations. Several cladoceran species, and especially *Diaphanosoma brachyurum*, were positively influenced by liming. After fish introduction, first *Bosmina longirostris* and *Ceriodaphnia quadrangula* and, some years later, *Daphnia longispina*, became the dominant zooplankton. The changes in the crustacean community are discussed in relation to planktivore fauna. During the limed and fishless condition, high densities of phantom midge larvae (*Chaoborus*) and waterboatmen (Corixidae) suppressed susceptible prey species. When these predators were reduced after fish introduction, the efficient herbivore *D. longispina* expanded and ultimately limited the abundance of other crustaceans. Thus, liming creates the potential for the development of a diverse fauna but the actual development of crustaceans in limed lakes is strongly influenced by predation and competition patterns.

STEPHENS, D. E. 1994. Evaluation of brown trout introductions in three southeastern Kentucky streams. Bulletin No. 94. Kentucky Department of Fish and Wildlife Resources. Frankfort, Kentucky. 27 p.

Brown trout fingerlings (3-5 inches) were stocked into nine Kentucky streams during 1986-1987 for the purpose of establishing self-sustaining populations capable of supporting a fishery. Previous water quality measurements and habitat assessments indicated that these streams could potentially support brown trout. Bark Camp, Laurel, and East Prong of White Oak creeks were selected from the nine streams to evaluate the success of developing natural populations of brown trout sufficient to create a fishery. Natural reproduction was documented in Bark Camp and East Prong of White Oak creeks but not in Laurel Creek. Reproductive success was insufficient to maintain a self-sustaining population of trout. Poor and limited spawning habitat were regarded as the primary factors precluding successful reproduction. Only Bark Camp Creek was selected for future stockings of 8 inch brown trout to provide a put-grow-take fishery.

STRANGE, C. D. and G. J. A. KENNEDY. 1979. Yield to anglers of spring- and autumn-stocked hatchery-reared and wild brown trout. Fisheries Management 10(2) : 45-52.

Tagging experiments are described where hatchery over-yearlings and similar sized wild brown trout were spring-stocked in two small angling lakes. This was followed in the autumn with a stocking of hatchery fingerlings and wild fish. The spring-stocked hatchery fish gave the best return to anglers of 9.3% over the first two seasons while the autumn stocked hatchery fish apparently suffered heavy over-winter mortality giving a return of only 1.3% over a comparable time period. Wild fish gave low return rates of 2.9% and 2.0% from spring and autumn stocking respectively although netting exercises indicated that these survived longer in the lake than hatchery fish. Analysis of the methods of capture indicated that hatchery fish were more liable to be caught by bait fishing whereas fly fishing was the most successful for wild fish. Estimates were made of the relative cost effectiveness of the various types of fish in terms of returns to the angler.

STRANGE, C. D. and G. J. A. KENNEDY. 1982. Evaluation of fluorescent pigment marking of brown trout (*Salmo trutta*) and Atlantic salmon (*S. salar*). Fisheries Management 13(3) : 89-95.

Fish farm and field trials have been conducted into the longevity and reliability of fluorescent pigment spray marking on brown trout and Atlantic salmon. These have shown that the technique produces high quality marks for a minimum of twenty months for brown trout and 7 months for Atlantic salmon. In addition a minimum size of 6.8 cm for the successful marking of brown trout fry has been established. High mortalities were found when the technique was used on fish which were subject to stress. Causes of stress are discussed and mortality rates of <1% have now been achieved.

SUNDELL, K., C. DELLEFORS and B. T. BJORNSSON. 1998. Wild and hatchery-reared brown trout (*Salmo trutta*) differ in smolt related characteristics during parr-smolt transformation. Aquaculture 167(1-2) : 53-65.

Morphological changes during parr-smolt transformation are generally less apparent in hatchery-reared than wild salmonids. The aim of the present study was to investigate possible differences between wild and hatchery-reared brown trout in regard to physiological characteristics during smoltification. Plasma growth hormone levels, hypo-osmoregulatory ability, gill Na^+,K^+-ATPase activity and condition factor were compared between wild and hatchery-reared fish from the same river stock, in two different streams on the Swedish coast. Plasma growth hormone levels were consistently higher in wild compared with hatchery-reared trout, and the growth hormone levels increased in wild fish from one of the streams after a 24 hours seawater challenge test. At the time of parr-smolt transformation, there was a peak in gill Na^+,K^+-ATPase activity, which coincided with the lowest plasma sodium levels. Wild fish possessed consistently higher gill Na^+,K^+-ATPase activity and lower plasma sodium levels compared with hatchery-reared fish. The condition factor of wild fish decreased throughout the smoltification period, in both river strains, whereas the hatchery-reared fish had consistently high condition factor. It is concluded that the artificial environment of hatchery-reared anadromous brown trout can depress the natural parr-smolt transformation, and that this may adversely affect the success of seawater migration and long-term survival of the fish.

SWARTZ, A. H. 1950. Report on the results from trout stocking in the Deerfield River. Journal of Wildlife Management 14(2) : 183-189.

To supplement information on the results of legal-sized trout in streams and rivers of Massachusetts, creels were conducted in the 1946 and 1947 seasons on the Deerfield River. In 1946, trout ranging from 9 to 13 inches were planted in the test section. This stocking included 7,840 brook trout, 3,050 brown trout, and 2,065 rainbow trout. The majority of the fish were released during March, prior to the open season. In 1947, the stocking comprised 4,600 of each of the three species of trout.

In 1946, brown trout contributed only 3% to the total catch. While that number only rose to 6.6% in 1947, the efficiency of recovery of brown trout was 12.6%. In total there was a 31% (average) return on the trout stocking done in 1947, that of brown trout being 35% using all recovery methods.

Because of the low returns to the fishery, it is advisable that stocking be de-emphasized and effort be placed on encouraging the production of the native trout.

TAGGART, J. B. and A. FERGUSON. 1986. Electrophoretic evaluation of a supplemental stocking program for brown trout (*Salmo trutta*). Aquaculture and Fisheries Management 17 : 155-162.

Over a 15 year period, hatchery brown trout (*Salmo trutta*) have been added to Lower Lough Erne, northern Ireland, to supplement declining native populations. Introductions have mainly comprised eyed ova and fingerlings, stocked into a number of rivers in the Erne drainage. Utilizing a natural genetic tag an electrophoretic assessment of the stocking program was undertaken.

The percentage hatchery genetic contribution in trout populations varied widely from river to river (19%-91%). Lough-caught brown trout (3+ and older) showed a substantial (21.5%) hatchery genetic component. Introgression of native and hatchery stocks was evident. The resultant deleterious genetic consequences for the conservation of the unique Lough Erne brown trout gene pool are discussed and alternative management strategies are proposed.

TAKKUNEN, T. 1993. The stocking of spawning adults as a method of brown trout (*Salmo trutta lacturis*) stock management. Suomen Kalatalous 59 : 3-10.

Hatchery-reared, sexually mature male and female brown trout were stocked directly into known spawning sites at the beginning of the spawning period in the Äyskoski and Huuhtajankoski streams of the Rautalampi Lake system. The percentage of marked trout that were spawning and redds made by them were visually observed as strong light on dark. The effect of the stocking on parr densities was researched by electrofishing during 1989-90.

The majority of the stocked trout were seen spawning during the observation period. The number of redds was at its highest in autumn 1989 at 143, after stocking 70 females. Without stocking any females in 1986, there were 22 spawning redds. The density of brown trout parr (0+) was highest, about 40 individuals per 100 m^2, in autumn 1990. Before the stocking of any adults, the average daily density was <1 individual per 100 m^2. All of the fish with known capture sites were recovered in the releasing area and no tagged fish were caught nine months after their stocking.

TAYLOR, A. H. 1978. An analysis of the trout fishing at Eye Brook – A eutrophic reservoir. Journal of Animal Ecology 47 : 407-423.

Statistical analysis of angling records from Eye Brook Reservoir for the five seasons (1 April to 30 September) 1966 to 1970 was carried out. The numbers of brown trout and rainbow trout caught each day from the banks and from boats were compared with the trout stocked, daily estimates of water level, surface water temperature, bottom water temperature, stratification, sunshine, rainfall, wind and counts of algae in the four group diatoms, green algae, blue-green algae and debris.

The rainbow trout fishing was more dependent on the stock of trout than was the brown trout fishing. The rainbow trout stock was high in the summer and low in the early spring, as were the catches of rainbow trout. High water temperature, blue-green algae in the water and low water level did not adversely affect the rainbow trout fishing. When a high rainbow trout stock coincided with cool water, the catch was also good.

Brown trout fishing from the bank was considerably poorer in summer than in the early spring and this appears to have been caused by the water temperature. At values above 18° C, there was a marked fall in brown trout catches, especially from the bank. This decline became more pronounced with increased values above 18° C. Rainbow trout fishing was less sensitive to high water temperature.

During the first few days of the season, trout fishing from the bank was good, even though the trout stocks were very low. The trout fishing from boats was poor. Subsequently, until the water temperatures rose above 13° C, brown trout fishing from the bank continued to be good and brown trout fishing from boats was about average. The rainbow trout stock continued to be very low and the rainbow trout fishing was generally bad.

The trout fishing did not appear to be affected by the presence of large numbers of algae. Rainbow trout fishing was very good at such times but there were more rainbow trout to be caught. Brown trout fishing at the bank was poor but this was at least partly attributable to the higher water temperature. Two exceptional effects were that the brown trout fishing was poor when there were large numbers of diatoms present, and the brown trout fishing deteriorated during heavy blooms of blue-green algae or *Ceratium.*

The fishing was better during windy, dull periods than when the weather was calm and sunny, and the reservoir stratified. Trout fishing from the bank was about average (rainbows) or better (browns) on the days when rough weather prevented boats being used, even though angling must have been difficult and the trout stocks tended to be lower.

TAYLOR, J. N., W. R. COURTENAY, Jr. and J. A. McCANN. 1984. Known impacts of exotic fishes in the continental United States. p. 322-373. *In* W. R. Courtenay, Jr., and J. R. Stauffer, Jr. [eds.]. Distribution, Biology and Management of Exotic Fishes. John Hopkins University Press. Baltimore, Maryland.

Brown trout have been known to negatively impact a waterbody following stocking. There may occur a diet overlap between the brown trout and native species, therefore causing competition to occur. Brown trout are also notorious predators and are currently thought to be responsible for declines of native salmonids, such as brook trout, golden trout and cutthroat trout, in the United States.

TEMPLETON, R. G. 1970$_a$. The movement of hatchery-reared brown trout introduced into the River Nidd, Yorkshire. Yorks, Ouse : Hull River Authority Publication.

TEMPLETON, R. G. 1970$_b$. Movement of hatchery reared brown trout introduced into the River Ure at Ripon Yorkshire. Fisheries Management 1 : 35-43.

For many years in Yorkshire, brown trout (*Salmo trutta*) reared at the River Authority's trout hatchery at Keld Head, Pickering, have been introduced into rivers for various angling clubs. A tagging program was undertaken in 1966 in an attempt to determine their movement and growth after inroduction. The first phase of the program took the form of a pilot project to determine the likely percentage of tags returned and possible limits ot movement. Assuming moderate success, a larger tagging operation was planned during subsequent seasons to study growth and movement. During the pilot project at Ripom, from 1966-67, 500 eight inch and 300 ten inch tagged trout were introduced and details of recaptures and movement of the introduced fish are given.

Of the 800 fish released, those introduced at Sharow spread up nd down stream with a slight bias for downstream movement, whereas those introduced at the lower stocking points tended to move upstream. Over the two seasons, 1.2% of tagged fish were taken outside of the club's water. The farthest point of recapture was 10 miles upstream and 45 miles downstream in tidal waters. Just over 90% of the returns had been recorded by mid-June. It is thought that angling clubs having fishing rights of much less than one mile on such a river would lose a high percentage of any introduced hatchery fish unless neighboring clubs are also stocking, then the exchange becomes one of mutual benefit.

TEMPLETON, R. G. 1971. An investigation of the advantages of autumn and spring stocking with brown trout (*Salmo trutta*) in a Yorkshire reservoir. Journal of Fish Biology 3(3) : 303-324.

Batches of trout have been introduced into Chelker Reservoir in Yorkshire in the autumn and spring since the 1870s for angling purposes. Six batches of tagged, hatchery-reared brown trout (*Salmo trutta*) were introduced from autumn 1966 to spring 1969. During the angling season fish introduced in the spring give better catches than those stocked in the autumn. At the beginning of the season the larger fish in the spring batch are caught more often than the smaller fish from that batch throughout the season. The population, available to the angler from the shore was estimated to be 1,491 in 1968, with 722 fish/km of shoreline. More fish survive to a second season in the reservoir than is apparent from the number of tags returned. Fish introduced in the spring usually begin growing before those introduced in the autumn, thereafter growth rates varied. The growth rate was independent of the number of fish stocked up to the numbers put in.

Batches of tagged trout were retained at the hatchery up to nine months to gain relevant experience of post-tagging mortalities, tag loss rate and effect of tags on growth.

THORFVE, S. and M. CARSTEIN. 1998. Post-stocking behaviour of hatchery-reared European grayling (*Thymallus thymallus*) and brown trout (*Salmo trutta*) in a semi-natural stream. Fisheries Management and Ecology 5(2) : 147-159.

Hatchery-reared, juvenile European grayling (*Thymallus thymallus*), and brown trout (*Salmo trutta*), were each stocked six times into an area of a semi-natural stream. The order in which the two species were released was switched after every second experimental stocking. Temporal and spatial post-stocking dispersal, effects of previously stocked species, feeding behaviour and the influences of sex and size were studied. During each 48 hour experimental release period, some fish were recaptured in a trap situated 200 m downstream from the stocking site, and fish remaining in the stream after each experimental release were caught by electric fishing. Significantly more grayling than trout moved downstream and left the semi-natural stream. Proportions of stocked grayling recaptured in the trap within 2 hours and from 2 to 48 hours post stocking in the stream were 36.4% and 10.0%, respectively. Corresponding recapture rates for brown trout were both 1.5%. Most of the grayling and brown trout that did not leave the stream early were recaptured in deep, slow-moving watèr at low velocities in the release area. The presence of grayling at the time that the brown trout were stocked resulted in significantly fewer brown trout staying in the upper part of the stream.

THORN, N. C., C. S. ANDERSON, W. E. LORENZEN, D. L. HENDRICKSON and J. W. WAGNER. 1997. A review of trout management in Minnesota streams. North American Journal of Fisheries and Aquatic Sciences 17(4) : 860-872.

Agricultural development after 1850 in southeast Minnesota degraded instream habitat, and by 1900, the native brook trout (*Salvelinus fontinalis*) was extirpated from most streams. By the 1940s, after 60-70 years of stocking, the exotic brown trout (*Salmo trutta*) was the most common trout, but abundance was low and limited by lack of reproductive habitat. Soil conservation practices of the 1930s and 1940s and watershed management under Public Law (PL) 566 in the 1950s and 1960s reduced flooding, erosion, and sedimentation and increased infiltration and base flow. By the 1970s, brown trout reproduction was common, but abundance was still low. Fisheries managers of the Minnesota Department of Natural Resources assumed that adult habitat limited abundance, so they improved instream habitat in streams with public access, which increased brown trout abundance in some streams. Experimental management since 1975 has shown that the lack of adult habitat did limit trout abundance. This management regime has also enabled the quantification of habitat quality and has developed a decision key for brown trout management. When land management has degraded stream habitat, land treatments, acquisition of riparian corridors, and instream management are necessary to rehabilitate habitat and provide recreational fisheries.

THORPE, L. M., H. R. RAYNER and D. A. WEBSTER. 1947. Population depletion in brook, brown and rainbow trout stocked in the Blackledge River, Connecticut in 1942. Transactions of the American Fisheries Society 74 : 166-187.

A section of the Blackledge River, 1.7 miles long, was blocked off by weirs and fish traps and a total of 4,757 marked brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*) were stocked in the experimental area in three plantings. Only a small number of the marked trout attempted to leave the area as indicated by the 46 fish taken in the traps. Subsequent recapture of these trout which were tagged indicated no inclination to move any great distance. The mortality of the marked trout after planting was slight during the period of observation except in one planting where the brook and brown trout stocked showed advanced symptoms of furunculosis. The total catch of marked trout during the season of April 17 to August 31 was 3,446 trout taken by 3,152 anglers spending 9,746 hours on the stream. There was about an 80% return of the available population from each planting and from each of the three species of trout planted. Of the 97 unmarked trout which were caught, only 23 were judged to be "wild" fish, the others being recently stocked trout which had moved into the area from adjoining waters before the weirs were in place. The distribution of the angling pressure was such that each planting was depleted within a few days. About three fourths of the total catch of trout made from any one planting was taken within four days of the date of stocking. The population of brook trout was depleted most rapidly, that of brown trout most slowly, and rainbow trout were intermediate. Only five days of fishing were provided during the season where the catch per unit of effort approached one trout per hour or more. There was a high correlation between the population of trout in the stream and the catch per unit effort except in the second planting of brown trout. The relationship between the available population and the catch per unit effort showed progressively higher yields for the same number of trout as the season advanced. Because of the rapid population depletion, in only one instance could possible differences in behavior between newly stocked trout and those from previous plantings be noted. The number of brown trout caught from the second planting showed no correlation with the fishing effort while brown trout caught from the first planting at the same time were closely related to the fishing effort. The distribution of each angler's catch indicated that under a limit of 15 fish about one-third of the total number of anglers accounted for three-fourths of the catch on the first few days of fishing following each planting.

TIMMERMAN, A. 1999. Brown trout stocking assessment, Lower Mill Creek. File Report. Ontario Ministry of Natural Resources. Guelph, Ontario. 4 p.

Approximately 1,500 yearling brown trout were stocked at three sites in Lower Mill Creek in the City of Cambridge on May 6, 1998. These brown trout were acquired from the Normandale Fish Culture Station and were of Ganaraska/Normandale stock. All fish were adipose fin clipped and weighed an average of 62 grams per fish. Electrofishing was conducted in October 1998 at three sites to assess the survival and growth of these trout as well as determine the general species composition of this section of the creek. Electrofishing was also conducted in the spring of 1999 during an electrofishing training course.

Twelve fish species in addition to brown trout were captured. Some of the other resident species included northern pike, rock bass, yellow perch, largemouth bass and smallmouth bass. In total, 14 brown trout were captured indicating that at least some of the stocked trout had survived the hot, dry conditions during the summer of 1998. Some of the trout had moved downstream from the lowermost stocking site. Mean total length/fork length was 218/208 which represented an average growth of 31 mm in total length and 28 mm in fork length. There was evidence of high angling activity in two portions of the creek.

TOIVONEN. J., H. AUVINEN, E. IKONEN, T. ALAPASSI and U. KOKKO. 1994. Results of stocking with brown trout (*Salmo trutta lacustris*) in Finnish Lakes and Rivers. European Inland Fisheries Advisory Commission Technical Paper 42 (Supplement 1) : 143-151.

The paper deals with the tagging experiments with brown trout (*Salmo trutta lacturis*) in Finnish lakes in the sixties and seventies. These were performed on fish in different kinds of lakes in order to monitor profitability and to find the best fish size and date for stocking. The yield per 1,000 stocked smolts varied between 0 and 600 kg. The recommended minimum size for stocking is 18 cm, and 25 cm in most of the regulated lakes. Stocking in spring has given considerably better results than stocking in autumn. The best results have been obtained in large, clear, oligotrophic lakes with dense stocks of vendace (*Coregonus albula*).

TOWNSEND, C. R. and T. A. CROWL. 1991. Fragmented population structure in a native New Zealand fish: An effect of introduced brown trout? Oikos 61(3) : 347-354.

We conducted a survey of 198 sites in eight catchments in the Taieri River drainage of the South Island, New Zealand, and found a strong negative association between the distributions of introduced brown trout and native *Galaxias vulgaris*. Although habitat degradation due to agricultural and forestry practices was associated with lower densities of fish, these reductions were found in all fish species and did not help to explain the trout/galaxiid pattern. Statistical analyses incorporating a variety of physical, chemical and biological variables showed that presence and abundance of *G. vulgaris* were best predicted by the absence of trout. In most cases, *G. vulgaris* were only found above waterfalls that were large enough to inhibit trout migration. We suggest that predation is the most likely mechanism for the observed disjunct distributions between the native fish and trout. Moreover, the strong predation effect is probably a result of New Zealand's comparative paucity of native piscivorous fishes, resulting in a native fish fauna having no evolved defenses.

TREMBLEY, G. L. 1943. Results from plantings of tagged trout in Spring Creek, Pennsylvania. Transactions of the American Fisheries Society 73 : 158-172.

Data on anglers' catches, the growth and migration of stocked trout, and the efficiency of fall and spring plantings were obtained by means of a creel census in Spring Creek, Pennsylvania, during 1939. Of 2,130 tagged trout planted, 50.8% were recovered by anglers. Due to heavy fishing pressure, more than 40% of all tagged trout taken during the entire season were removed on the first day. A high first-day kill (76% of the total recoveries) of brook trout was noted. The quality of fishing declined rapidly during the early season. Fishing for brook trout was good for only a few days, brown trout fishing was fair for about a month, while rainbow trout fishing lasted slightly longer. Catches of tagged trout after 6 weeks were negligible. Only 10 trout were recovered during 1940 and 1 during 1941. Six of these fish were brown trout and five were rainbow trout. There was no evidence that any brook trout survived from one fishing season to the next.

Growth studies of trout planted in the fall indicated that rainbow trout grew fastest, followed by brown trout and brook trout. There was evidence that the growth rates of brown trout and rainbow trout decreased as the size of the fish increased. This was not true of brook trout.

Migrations of fall-planted trout were not extensive. Those undertaken averaged considerably less than 1 mile. Brown trout favored upstream and brook favored downstream movement, while rainbow trout moved in equal numbers in either direction. Spring-planted trout, captured after less than a month in the stream, had moved very little. A majority of brook trout and brown trout remained within the planting areas. About half of the rainbow trout had migrated.

Fall planting of the three species of trout was nearly as efficient as spring planting, as 49% of the former and 54% of the latter were recovered. Eight percent more brown trout from the fall-plantings were recovered than from the spring planting. Recoveries of spring planted brook trout and rainbow trout exceeded those of fall planted trout by 8.8% and 13.6%, respectively. Contrary to the common belief of anglers, fall-planted trout did not become "wild" over the winter. They were taken even more readily in the early fishing season than were trout of the spring plantings. The high returns from the fall plantings were attributed largely to the heavy fishing pressure, the moderate winter conditions, the lack of important predators, and to a possible scarcity of wild trout from natural spawning in Spring Creek.

TRZEBIATOWSKI, R. 1993. Utilization of small streams for production of sea trout (*Salmo trutta*) smolts. Fortschritte der Fischereiwissenschaft 11 : 77-81.

The studies conducted over 1986-1989 were aimed at developing economic methods of sea trout (*Salmo trutta*) production under natural conditions by stocking fry into small streams. The streams were selected in a survey of those available. The first stage of the study involved a spring stocking of the streams selected with, alternatively, the swim-up fry with resorbed yolk sacs and the fed fry aged 2 months, previously kept in well water (6° C temperature). The rates of survival to parr stage of the swim-up and the fed fry were 9.4-15.4% (13.1% on the average) and 31.4-59.0% (45.9% on the average), respectively. The second stage (1988-1989) involved testing the possibility of using small and shallow streams to produce autumn sea trout parr, the streams offering the subsequent smolts no chance of descent. The measured and tagged parr from 6 streams, stocked in spring with the fed fry, were transferred to River Gowienica in autumn/winter. The descending smolts were captured in spring 1989. A total of 771 smolts aged 1+ were caught in 1989, while 10 smolts aged 2+ were caught next year, i.e. the total number of smolts captured was 781, which makes up 24.1% of the fish released.

TURNER, S. E. 1972. Brown trout literature review. Federal Aid Project MO F-1-R-21, Job No. 1/S. Missouri Conservation Commission. Jefferson City, Missouri. 22 p.

In this publication 51 papers are reviewed and annotated with information pertaining to biology, management and stocking of brown trout (*Salmo trutta*).

TURNER, S. E. 1974. Fisheries management planning and research: Study of the introduction of brown trout in two Missouri rivers. Federal Aid Project MO F-1-R-23, Job Nos. 2&3, Final Report. Missouri Department of Conservation. Jefferson City, Missouri. 36 p.

UGEDAL, O., B. FINSTAD, D. DAMSGARD and A. MORTENSEN. 1998. Seawater tolerance and downstream migration in hatchery-reared and wild brown trout. Aquaculture 168(1-4) : 395-405.

Seawater tolerance and downstream migration were examined in 2-year old hatchery-reared brown trout (*Salmo trutta*) and compared with wild downstream migrating trout in the spring 1994 and 1995, using a fish trap in the River Halselva, northern Norway. At release, seawater challenge tests (72 hours, 34‰) showed that about half of the variance in seawater tolerance of hatchery-reared fish was explained by fish size. On average, 34% of the released trout migrated downstream, whereas 44-51% had acceptable seawater tolerance at release (seawater challenge plasma chloride ≤160 m/mol). The migration tendency in hatchery-reared fish increased with increasing fish size at release. Migrating hatchery-reared fishes and first-time migrants of wild trout showed a well-developed hypo-osmoregulatory capacity. Downstream migration in this brown trout stock therefore appears to be associated with a well-developed seawater tolerance.

VALKEAJARVI, P. 1993. Profitability of brown trout (*Salmo trutta*) stocking and the migration and growth of smolts in the Rautalampi Lake system. Suomen Kalatalous 59 : 57-71.

VEHANEN, T. 1995. Factors influencing the yield of brown trout (*Salmo trutta lacustris*) in northern Finnish lakes. Fisheries Management and Ecology 2(2) : 121-134.

Lake-to-lake variation in brown trout (*Salmo trutta lacustris*) yield from stocking was examined in 34 lakes in northern Finland. The trout were mainly stocked as 2-3-year-old fish. Catch statistics were compiled with information on water quality, water level fluctuations, fishing effort and lake geomorphology. Absolute brown trout yields (kg/ha) increased with increasing stocking rate, but there was an indication of non-linearity at higher stocking densities. Relative yields (kg per thousand trout released) were highest at low stocking rates. Stepwise multiple regression analysis was used to determine the best predictive model for lake-to-lake variability in brown trout yields. Seventeen measured regressands were used initially, and then replaced with scores obtained in a principal component analysis of highly correlated water quality variables and species-specific fish yields. Three major determinants of brown trout yields in these lakes were found in both analyses: fish community, stocking rate and fishing effort. Brown trout yields from stocking were higher in lakes with proportionally high yields of vendace or vendace and whitefish and proportionally low yields of pike.

VEHANEN, T. 1997. Fish and fisheries in large regulated peaking-power river reservoirs in northern Finland, with special reference to the efficiency of brown trout and rainbow trout. Regulated Rivers: Research and Management 13(1) : 1-11.

The Oulujoki, Iijoki and Kemijoki rivers in northern Finland, all of them previously important rivers for the fishing of migratory salmonids, were dammed for hydropower production in the 1940s-1960s. Some 20 years after the construction of the last power plant, the fish communities, fishing and the effects of brown trout (*Salmo trutta lacustris*) and rainbow trout (*Oncorhynchus mykiss*) stocking were studied in fifteen reservoirs, five in each of these rivers. Test fishing, echo sounding and fish tagging were used to collect descriptive information about the fish communities and the distribution and movements of fish. Catch statistics were used to estimate the yields and the fishing in the reservoirs. The results showed similarity in the fishing effort and the fish stocks in the reservoirs studied. Cyprinids, especially roach (*Rutilus rutilus*), were the most numerous species in the area. The hydroacoustic survey suggested that most of the fish occurred near to the river banks. Fishing in these reservoirs has recently increased but it is mostly directed at predatory species rather than roach. The increase in the amount of fishing can partly be attributed to the stocking of rainbow trout of a takeable size (0.8-1.2 kg), which give good yields. Poor yields resulting from the previously standard stockings of brown trout smolts have been improved by stocking fish exceeding 30 cm in length. The results, however, show that stocking is not profitable in all the reservoirs. The future prospects for recreational rod fishing in the reservoirs are good, but improvements in the conditions for operating traps and gill nets are needed to optimize yields. This could include an intensive stocking of predatory fish, brown trout and rainbow trout.

VEHANEN, T. and J. ASPI. 1996. Classification of northern Finnish lakes and the suitability for the stocking of brown trout (*Salmo trutta lacustris*). Fisheries Research 27(1-3) : 37-49.

Because there are some 15,000 Finnish lakes exceeding 10 ha in area, there is a pressing need in Finland for the development of effective stocking strategies for various types of Finnish lakes. The most common predatory fish employed in stocking in Finland for the past few decades has been the brown trout (*Salmo trutta lacustris*), and the brown trout yield in lakes relies almost solely on stocking. Since the resources of the fisheries managers are limited, it would be useful if an empirically derived lake classification scheme were made available for them, to enable them to plan and implement monitoring programmes to suit each individual lake.

A cluster analysis (Ward's minimum variance method) was used to classify 33 lakes in northern Finland on the basis of yields of seven most common species: brown trout, vendace, whitefish, perch, pike, burbot and roach. The success achieved in the stocking of brown trout was compared between the various lake clusters. A discriminant analysis was used to develop a discriminant criterion to classify each lake into one of the clusters on the basis of species composition and ten environmental variables.

The results suggested that, when based on catch statistics, cluster analysis can produce an objective classification scheme. Relative brown trout yield (kilograms per thousand fish released) seemed to be higher in the cluster with a higher proportion of vendace. The importance of the use of proper stocking rate for different kinds of lakes was also revealed. Discriminant criterion based on both species composition and environmental variables rather reliably classified the lakes to correct clusters (76% and 70%, respectively).

VEHANEN, T., P. HYVARINEN and J. ASPI. 1998. Dispersion of stocked brown trout (*Salmo trutta*) and landlocked salmon (*Salmo salar*) from stocking sites in Lake Oulujarvi, Finland. Fisheries Management and Ecology 5(3) : 177-188.

Movement and recaptures of two hatchery-reared brown trout (*Salmo trutta*) stocks and landlocked salmon (*Salmo salar*) released at different sites in regulated Lake Oulujaervi, were studied in relation to release site. Five groups of fish from each stock were released in approximately equal numbers. Most of the fish released in June and July were recaptured within 3 months, whereas the majority of the fish released in early winter (October and November) were caught the following spring, about 7-9 months after stocking. The release site had a significant effect on recapture rate. The results showed that fishing restrictions targeted mainly at gill net fishing are needed to preserve the stocked fish from overfishing. Significantly fewer recaptures were observed from the landlocked salmon stocking compared with brown trout. The recaptures from the landlocked salmon stocking indicated more active movement and less clumping compared with the two brown trout stocks.

VEHANEN, T., P. HYVARINEN and A. HUUSKO. 1998. Food consumption and prey orientation of piscivorous brown trout (*Salmo trutta*) and pikeperch (*Stizostedion lucioperca*) in a large regulated lake. Journal of Applied Ichthyology 14(1-2) : 15-22.

Food consumption and prey orientation of stocked brown trout (*Salmo trutta*) and pikeperch (*Stizostedion lucioperca*) were studied in Lake Oulujaervi, a regulated lake situated in northern Finland. A total of 454 brown trout and 451 pikeperch were sampled throughout 1994-96. Vendace (*Coregonus albula*) was the dominant prey for brown trout, and smelt (*Osmerus eperlanus*) for pikeperch. There appear to be significant differences in prey handling: brown trout ate significantly more prey fish head first whereas pikeperch consumed prey equally head or tail first. Estimated by bioenergetics models, 9.1-56.7 % of the annual age 0 + vendace biomass could be consumed by the two predators. However, when the vendace year class is low, a shift to other prey species or larger size vendace is likely to take place. If fishing mortality on brown trout in particular is reduced, the consumption of vendace can increase to the extent where an entire year class may be depleted. We stress that the adjustment of the stocking rate of predators to correspond to the abundance of prey fish is, therefore, one of the key factors in fisheries management.

VERMONT DEPARTMENT OF FISH AND WILDLIFE. 1993. The Vermont management plan for brook, brown and rainbow trout. Vermont Department of Fish and Wildlife. Waterbury, Vermont. 73 p. + appendices.

Brown trout enjoy less angling popularity than either rainbow or brook trout, however, they demonstrate the best chance for multiple year survival in streams and rivers than either of the other species. Brown trout should not be introduced into ponds with brook trout as they will likely be detrimental to the population. The advantages of catching large fish must be weighed against the loss of a brook trout population.

VESTAL, E. H. 1954. Creel returns from Rush Creek test stream, Mono County, California, 1947-1951. California Fish and Game 40 : 89-104.

This paper reports the results of the first five years (1947 through 1951) of a continuing complete creel census on Rush Creek Test Stream, a 3.7 mile section of a small California trout stream.

Rush Creek Test Stream was established by the California Department of Fish and Game to test the success of existing planting procedures and to find ways of improving them. Large in-season plants of marked catchable rainbow trout and marked fingerling rainbow and brown trout were made in the first three years to determine over-winter survival of such fish.

During the five-year census period, 33,431 anglers fished 118,408 hours and caught a total of 65,935 wild and planted trout. Planted trout contributed 59,362 (90%) of the total catch, while wild trout contributed 6,573 (10%). The catch of wild brown trout remained about the same each year, despite the heavy fishing pressure, while the catch of wild rainbow and eastern brook trout declined.

Of 69,904 marked catchable rainbow trout planted, 58,015 (83%) were caught by anglers; 82.8% in the season of planting and 0.2% in succeeding seasons. This excellent yield demonstrated the value of in-season, spaced plantings of such fish for maintaining reasonably good angling in a small, heavily fished stream.

Of the 13,395 fingerlings planted, only 386 (2.9%) were caught. Rainbow trout gave a slightly greater return (3.2%) than brown trout (2.6%). Of 12,000 subcatchables planted, 994 (8.3%) were caught. The spring-spawned strain gave a better return (12.5%) than the fall-spawned strain (4.1%), but data were insufficient to prove any superiority. These low returns illustrate the impracticability of maintaining angling in a small, heavily fished stream by stocking fry or sub-catchables.

The five year average intensity of use was 10 anglers and 35 angling hours per mile of stream per day. Average catch per angler day was 2.0 and the average catch per angler hour was 0.56. The average angler day was 3.5 hours. Forty-three percent of all anglers caught nothing, despite the heavy planting program. A reduced bag limit would probably distribute the fish more equitably and give the less expert anglers a better chance.

Catchables were recaptured rapidly. In 1950, a typical year, 45% of the total seasonal catch was taken in only one-seventh of the total fishing season. This suggests the desirability of more frequent plants well scattered along the stream.

The estimated total cost of stocking 70,000 catchable rainbow trout during the five years of the census period was $10,500. Placing a value of $10 on a day of trout angling in the Mono-Inyo area of California (based on probable costs to the fisherman), a total recreational value exceeding $300,000 was sustained at Rush Creek mainly by this stocking.

VON ROSEN, H. 1989. Class environmental assessment, fish stocking new waters: Brook Lake and Darling Long Lake. Ontario Ministry of Natural Resources. Carleton Place District, Ontario.

In Brook Lake the possibility of introducing brown trout appears feasible based on other studies. Reports from Summit Lake waters demonstrate that brown trout will experience rapid growth and can withstand competition from warmwater species as well as taking advantage of the coldwater forage.

Due to the unavailability of brown trout, rainbows were stocked into Darling Lake in 1977. At this time it seems that the introduction of brown trout into both lakes would be the most advisable route to follow, as opposed to further rainbow trout plantings.

WAHAB, M. A., H. P. STIRLING and D. A. ROBERTSON. 1989. Influence of brown trout (*Salmo trutta*) predation on the benthic fauna of earthen ponds. Aquaculture and Fisheries Management 20(2) : 147-158.

Sections of the bottom of three earthen fish ponds in central Scotland were enclosed to prevent access by juvenile brown trout (*Salmo trutta*) stocked at different densities from July to October. Monthly benthic samples were taken inside and outside the enclosures with a suction sampler. The benthos was dominated by Oligochaeta, whose density and biomass were significantly lower outside the enclosures; production was also lower outside but the P:B ratio was much higher. Total chironomidae were more abundant outside, but not the larger predatory species which appeared to control the inside population. Species diversity of Oligochaeta and Chironomidae was greater outside while mean size was reduced, presumably as a result of size-selective predation by trout. Numbers of Mollusca and Asellisae were lower in the presence of fish, but Hirudinea and Sitalidae were unaffected. Increasing fish density boosted chironomid numbers and biomass, indicating a predominant response to organic enrichment, but reduced the numbers of most other benthic groups presumably as a result of predation.

WALES, J. H. 1946. Castle Lake trout investigation. California Fish and Game 32(3) : 109-139.

Castle Lake was chosen for experimentation because of its typical character; because it has a road to it which makes for above average fishing intensity; because it is so located that all anglers can easily be checked; and because it is close to the District Fisheries Headquarters and State Fish Hatchery at Mt. Shasta.

The objectives of this investigation were to determine the most suitable species of trout to plant in mountain lakes of this type, the optimum size of fish at planting time and the optimum number to plant. Three species were used in equal numbers, but the question of the most suitable was obscured by the fact that in a mixed population the success of the component species may be quite unlike their success if they inhabited the lake singly.

There is practically no natural propagation of the rainbow, brown and brook trout, and as the hatchery-planted fish were marked it was a simple matter to compute survival rates. All fish planted since 1938 have been recognizable either through marks or their lack, and all catches have been checked from 1941 through 1945.

Percent of catch (average of 1941-45, inclusive): rainbow trout 35%, brown trout 47%, brook trout 15% and mackinaw 3%.

From 1938 to 1945 the numbers of rainbow, brown and brook planted have been approximately the same. The great differences in the percentages above indicate the dissimilar survival rates of these three species.

The average total number of pounds of trout caught annually was 489, working out to 10.4 pounds per acre. This demonstrates an even greater difference between the three planted species despite nearly equal numbers stocked.

Percent survival to the anglers:
- (a) Planted Fingerlings:
  - Rainbow: 0.5-7.8% (Average 3.5%)
  - Brown: 5.0-9.0% (Average 5.5%)
  - Brook: 0.4-3.2% (Average 1.9%)

- (b) Planted Yearlings:
  - Rainbow: 39%
  - Brown: 35%
  - Brook: 40%

The greatest loss, particularly in the fingerlings, is probably due to cannibalism during the first few days in the lake. The differences in the habits of these species may account for the survival differences. Brooks almost disappear from the catch by the third year after planting; browns play a significant part for five or six years after planting; and thus tend to build up a backlog of older fish; rainbows are intermediate between the other two.

From the standpoint of growth it appears that fingerling rainbow, brown and brook can be planted to advantage early in the season while they are still relatively small. The growth rate of the rainbow in Castle Lake is most rapid, that of the brown is second and the brook third. The condition factors for the Castle Lake fish are satisfactory and it is possible that the lake could carry more trout.

From the standpoint of survival it does not appear to make any difference what size the fingerling rainbow and browns are at planting time. However, for the best survival in the brook trout, the fingerlings should be as large as possible at planting time.

The food preferences of the four species of trout in the lake differ considerably. Marked differences also occur in the various age classes. "Surface" foods play a very important part in the diets of rainbow, brown and brook trout but not in the mackinaw. The "bottom" foods are very important to all four species. The plankton and fish eaten vary in volume and frequency of occurrence from species to species and age group to age group. The rainbow eat plankton but almost no fish, whereas the brown and mackinaw eat fish but little or no plankton. The rainbow and brook, though displaying some differences, are fairly much alike. The browns are dissimilar and the mackinaw are unique.

The following costs are for caught fish, both when planted as fingerlings and when planted as yearlings:

Cost-per-fish Caught by Angler

Planted as:	Rainbow	Brown	Brook
Fingerlings	$0.30 each	$0.19 each	$0.69 each
Yearlings	0.13 each	0.15 each	0.13 each

With a mixed population and consequent heavy predation the brown fingerlings or the rainbow and brook yearlings are the most economical to plant.

It seems reasonable to assume that a mixed population such as that which has existed in Castle Lake is not as efficient from the standpoint of trout production as a population of one species. Beginning in 1946 this belief will be tested by stocking with brook trout alone.

WATKINS, T. J. 1993. Effects of stocking on the brown trout (*Salmo trutta*) population in Augusta Creek, Kalamazoo County, Michigan. M. Sc. Thesis, Michigan State University. Ann Arbor, Michigan. 66 p.

WEBER, J. R. 1988. Return to the creel of brown trout stocked in the Great Lakes as yearling and fall fingerlings. Federal Aid Project F-53-R-4, Final Report. Michigan Department of Natural Resources. Lansing, Michigan.

Fall fingerling and yearling brown trout were fin clipped and stocked in Thunder Bay, Lake Huron, an area with an established brown trout sport fishery. A creel census was conducted from 1985-87 to determine the relative survival of the two life stages. Fish stocked as yearlings made up 96% of the return of marked fish. Unmarked fish of unknown origin were also present in the catch but not in numbers great enough to have a significant impact on the results of the study. Other prominent species in the catch were pink salmon in 1985 and chinook salmon in 1985-87. A nine day festival in July accounted for an average of 30% of the annual fishing effort and 35% of the salmonid catch. July was the most productive month for brown trout fishing. Over 90% of the annual catch consisted of ages 2 and 3, but the 1984 year class exhibited relatively high survival. This may have been related to its larger size at stocking. Continuous monitoring of the fishery from its inception has indicated that recent returns were lower, probably related to the increase in predators. The variable return of recent plants suggests that additional strategies such as changing stocking practices, increasing size at stocking, and experimenting with triploid fish, may significantly improve returns to the fishery.

WEBSTER, D. A. 1950. Fishery research program at Cornell University. Progressive Fish Culturist 12(2) : 77-80.

Following programs concerning the returns of lake trout, rainbow trout and smallmouth bass stocked in Cayuga Lake, a study of the survival of hatchery-reared brown trout was similarly implemented. These studies are currently being conducted on a tributary of the lake in response to concern surrounding the survival of hatchery trout in rivers. The initial project is looking at the effect of growth rate on survival.

WEBSTER, D. A. and G. S. LITTLE. 1944. Further observations on the food of newly planted brown trout (*Salmo trutta*) in Six Mile Creek, near Ithaca, New York. Copeia 1 (1944) : 56-57.

Six Mile Creek, New York, was used as a study site to determine the food of recently released two-year-old brown trout. Twenty to twenty-seven hours following stocking the amount of food in individual stomachs ranged from a few large to hundreds of smaller organisms. Mayfly nymphs (mostly *Baetis*) accounted for 90% of the volume of food consumed. The remaining 10% consisted of Diptera pupae, Chironomid larvae, stonefly nymphs, caddis larvae, plant material (needles, seeds, buds), sow bugs, gravel and fish.

Two days following planting it was observed that brown trout occasionally fed from the surface, taking advantage of stoneflies which were drifting there.

Five days following stocking, the fish stomachs held less food than during the first stomach analysis. Approximately twenty genera of prey food were present, including spiders, ants, earthworms, and slugs. No fish from previous plantings were caught and therefore no comparisons could be made.

WEISS, S. and H. KUMMER. 1999. Movement of wild and experimentally stocked brown trout (*Salmo trutta*) before and after a flood in a small Austrian stream. Fisheries Management and Ecology 6(1) : 35-45.

Weirs and traps were used to monitor the movement of two strains of stocked brown trout (*Salmo trutta*). Within 24 hours of stocking, 15% (*n*= 13) of a Danish strain and 21% (*n*= 19) of a hybrid strain moved at least 100 m from their release site. In the following 5-6 days, no further movement was found for Danish fish, but hybrid fish continued to move, totaling 32% (*n*= 29) of the fish stocked. During this same period, 36 wild brown trout (3.5% of the population) were captured, moving over the weirs. Two weeks later, and one week after a flood, 70% (*n*= 59) of the Danish strain were recovered within their release sites and 89% (*n*= 76) were recovered during an electric fishing survey within the 3.5 km-long experimental area. In contrast, 43% (*n*= 31) of the hybrid strain were recaptured in their release sites and 49% (*n*= 45) within the experimental area. The total recapture of wild adult fish was only 16% (*n*= 41). The flooding event was insignificant in comparison with strain-specific behaviours in determining patterns of movement and residency.

WEISS, S. and S. SCHMUTZ. 1999$_a$. Response of resident brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) to the stocking of hatchery-reared brown trout. Fisheries Management and Ecology 6(5) : 365-376.

Two strains of hatchery-reared adult brown trout (*Salmo trutta*) [208-334 mm total length (TL), n=591] were individually marked and released into a limestone stream. The estimated survival after one month (86%, n=508) was comparable to that for resident brown trout and rainbow trout (*Oncorhynchus mykiss*) (89%, n=771), but declined to 14% (n=83) after 8 months compared with 52% (n=451) for resident brown trout. The movement of resident trout out of stocked stretches was higher (14%) than from control sites

(5%), but the population size in both individual sites and the overall study area were unaffected. The growth of resident brown trout was unaffected by stocking but rainbow trout showed lower growth rates in stocked *versus* unstocked stretches both one and 8 months after stocking (*P*<0.002).

WEISS, S. and S. SCHMUTZ. 1999$_b$. Performance of hatchery-reared brown trout and their effects on wild fish in two small Austrian streams. Transactions of the American Fisheries Society 128(2) : 302-316.

Two small streams of contrasting physiochemical character, one crystalline and one limestone, were experimentally stocked with brown trout (*Salmo trutta*). The study design involved doubling (three sites) or tripling (three sites) the number of large-sized resident fish (>179 or >199 mm total length, dependant on the stream) with an equal mixture of two hatchery strains; three additional sites were left unstocked as controls. In the limestone stream, short term survival (3 months) of hatchery fish (both strains) was 80%, compared with 90% for wild fish. In the crystalline stream, survival of hatchery fish was 48% and 62% (dependent on strain), compared with 49% for wild fish. After 12 months, the survival of hatchery strains declined precipitously (range: 1-19%), compared with wild fish (range: 13-52%), dependant on stream and strain. After 3 months, about half of the recaptured hatchery fish were caught outside the 200 m long sites in which they were stocked. Percent movement of wild fish was affected by stocking density in the limestone stream (control, 5%; double treatment, 14%; triple treatment, 20%) but was unrelated to stocking density in the crystalline stream (control, 32%; doubled, 20%; tripled, 28%). Stocked strains on average lost weight (7-11%) over the first 3 months in the limestone stream but gained weight (5-25%) over the same period in the crystalline stream. Growth of wild brown trout was negatively affected by stocking in the crystalline stream but was unaffected in the limestone stream. Despite the recorded movements, there was no significant change in the population size or biomass of brown trout populations due to stocking in either stream.

WELCOMME, R. L. 1988. Introductions of *Salmo trutta*. p. 252-256. *In* International Introductions of Inland Aquatic Species. FAO Fisheries Technical Paper 294. Food and Agriculture Organization of the United Nations. Rome, Italy. 318 p.

A total of 1,354 introductions of 237 species into 140 countries are analyzed. The number of introductions carried out rose from the middle of the last century until the 1960s and have lessened since then. Introductions have been made for aquaculture, management of inland water fisheries, ornament and control of unwanted organisms. Many introductions have been made for purposes unknown or by accident. The introduction of new species of aquatic organism involves a number of risks including, degradation of the host environment, disruption of the host community, genetic degradation of the host stock, introduction of diseases and socio-economic effects. Major risks of damage to native environments and fish communities are associated with introductions of species which stunt and with major predators. It is concluded that the introduction of new species is a valuable management tool but, because of the risks to the host community, any further introductions should be made only after careful consideration on any impacts.

The native range of the brown trout (*Salmo trutta*) is in Europe and western Asia. Currently they are distributed almost as widely as rainbows but with less success in warmer climatic zones where stocks are generally limited to above 1,500 m. Where *S. gairdneri* and *S. trutta* have been introduced together the two species separate thermally with *S. trutta* in the cooler higher latitude and altitude streams. The success of the species has been limited by its lesser suitability for aquaculture with the result that introductions have remained primarily for sporting purposes. This trout has also been implicated in the decline of local species of fish particularly in New Zealand where *Galaxias divergens* and *G. argenteus* have largely disappeared from waters where brown trout are present.

The brown trout is blamed for damaging native *Orestias* populations in Bolivia and has established itself in high Andean streams and there is also a small population present in Lake Titicaca.

WELSH WATER AUTHORITY. 1986. The survival and physiological responses of brown trout stocked in two acidic upland lakes, before and after liming and an assessment of the performance of trout fisheries re-established in them. Fisheries Technical Report No. SW/86/30. 46 p.

WESTERMAN, F. A. 1961. On the history of trout planting and fish management in Michigan. p. 15-38. *In* Michigan Fisheries Centennial Report 1873-1973. Fisheries Management Report No. 6. Michigan Department of Natural Resources. Lansing, Michigan.

WIERICH, C. B. 1974. An initial study of the return and movement of brown and rainbow trout stocked pre-season and in-season and the use of wired areas in sustaining a catchable trout fishery after in-season stocking. Pennsylvania Fish and Boat Commission. Bellefonte, Pennsylvania.

WIGGINS, W. G. 1950. The introductory ecology of the brown trout (*Salmo trutta*) with special reference to North America. M. Sc. Thesis, University of Toronto. Toronto, Ontario. 109 p.

Brown trout have been introduced across North America as well as numerous countries worldwide. This paper focuses on the success of the brown trout in North America, with particular reference to Ontario waters. Topics which are discussed include potential predators, reproduction, diseases, competition, habitat parameters, movement and growth.

WILDE, C. W. 1956. Creel census on Wononscopomic Lake: Comparative recovery rates of brook, brown and rainbow trout in a Connecticut Lake. Federal Aid Project CT F-9-R. Connecticut State Board of Fisheries and Game. Hartford, Connecticut. 2 p.

The purposes of this project are:

- To determine the species of trout best suited for stocking Connecticut lakes.
- To determine the age class of trout best suited for lake stocking.
- To determine the most advantageous period or periods for lake stocking.

Thus far in the project certain tentative conclusions have been reached:

- Two-year old hatchery brown trout furnish the greatest overall returns to the angler.
- On the average, there is little difference in the recovery of two-year old brown trout stocked post-season, pre-season or during the season. Any slight difference in favor of spring planting is, in all probability, overcome by the savings in feeding and handling costs that accompany fall stocking.
- Two-year old rainbow trout furnish the greatest recovery as hold-over fish.
- There may be considerable merit in stocking yearling browns. This may be true only as long as the warm-water fish population remains small.
- Some in-season stocking is desirable. The presence of the hatchery truck seems to act as a magnet to draw anglers to the lake. Apparently, a large percentage of the angling fraternity believe a lake is fished out if it has not had a recent stocking.
- The yearly catch of lake trout is small, probably less than 50 fish a year and consists of mainly one and one-half to two pound fish. Apparently, lakers are more numerous and reach considerably greater size than is indicated by the creel census.

WILDE, C. W. 1957. Comparative recovery rates of brook, brown and rainbow trout in a Connecticut lake. Proceedings of the Northeast American Fisheries Society. 7 p.

WILEY, R. W. 1995. A common sense protocol for the use of hatchery-reared trout. American Fisheries Symposium 15 : 465-471.

The purpose of this paper is to describe the history of fish culture in Wyoming and its role in fish stocking. The first Wyoming hatchery opened in 1884 and today there exist 12 hatcheries across the state. Approximately nine million trout were stocked annually from 1987 to 1992, including those of the brown trout species. In the early half of the 20th century a statewide fisheries management plan dictated trout stocking methods. Brown trout were to be stocked in lakes of the lowest elevation, golden trout into the highest. While some species were stocked alone the brown trout could only be stocked alongside forage fish. There is now a demand for more current fish management guidelines. Suggested guidelines are as follows:

- Solve habitat problems prior to stocking with hatchery fish. Without proper habitat these fish will survive no better than those who are native to the area.
- Manage for native fish or wild fish wherever possible.
- Manage according to the fish capacity of the waters.
- Only stock fish in standing waters in which salmonid reproduction is limited or non-existent.

WILEY, R. W., R. A. WHALEY, J. B. SATAKE and M. FOWDEN. 1993. An evaluation of the potential for training trout hatcheries to increase post stocking survival in streams. North American Journal of Fisheries Management 13 : 171-177.

An average of 8.9 million trout (*Oncorhynchus* spp., *Salmo trutta*, *Salvelinus* spp.) were planted in Wyoming each year from 1987 through 1990; 86% were of subcatchable size (<8.25 inches) and 14% were of catchable size (≥8.25 inches). Of the total fish planted, 1.9 million subcatchable trout and 177,000 catchable trout were planted in streams. Harvest rates of trout stocked in streams was low (average, 5.7%), possibly because of the hatchery conditions under which they were reared. Hatchery-reared trout were raised in conditions far different from those of natural waters: densities hundreds of times those in the wild, nearly constant water flow and water temperature, regular feeding, lack of cover, and absence of predators. Hatchery trout may become disoriented, fail to seek cover, forage efficiently, and die when planted in streams with competing fish. Evaluating the survival of hatchery trout fed natural food, rearing hatchery trout in simulated natural conditions, raising them at moderate densities, and evaluating costs associated with management of wild and hatchery trout would provide additional means for judging the potential to train hatchery trout to survive in the wild. Such evaluations also would provide more criteria upon which to judge the success of planting hatchery trout.

WISCONSIN BUREAU OF FISHERIES MANAGEMENT AND HABITAT PROTECTION. 1999. An evaluation of stocking strategies in Wisconsin with an analysis of projected stocking needs. Wisconsin Department of Natural Resources. Madison, Wisconsin. 38 p.

For the year 1999-2000 there exist proposals for the stocking of brown trout in Lakes Superior and Michigan. Lake Superior is to receive fish from two separate strains. Fifty thousand trout of the Seeforellen strain from feral Lake Michigan brood stock and another 50,000 from a feral Soda Lake brood stock will be planted. All of these fish will be yearlings. Lake Michigan will receive 1,232,940 brown trout. Over half of these will be from a domestic brood stock (682,200 fall fingerlings and 242,550 yearlings). The remainder will be Seeforellen yearlings from feral Lake Michigan brood stock. The use of the Seeforellen brown trout in these two lakes has improved the brown trout fishery.

Brown trout are also stocked inland. In the past stocked wild brown trout have been known to have superior levels of survival to hatchery-reared brown trout. In northeastern Wisconsin native strains of brown trout also give greater yields than non-native strains.

It is recommended that approximately 55% of domestic brown trout and brook trout allocations be replaced by wild trout. The number of domestic brown trout planted will effectively shift from 564,240 (in 1999) to 253,200 (in 2000). Consequently the number of wild brown trout stocked will increase from 331,630 (in 1999) to 670,540 (in 2000).

WISCONSIN DEPARTMENT OF NATURAL RESOURCES. 1980. Fish management handbook. Wisconsin Department of Natural Resources. Madison, Wisconsin.

Trout stocking is an important and common tool in trout management. Almost all trout lakes, including the Great Lakes, depend almost entirely upon stocking since sufficient reproduction is lacking in these waters.

In general, brown trout in lakes do not furnish as successful a return as other species of trout because they are difficult to catch and large brown trout can severely limit the survival of those stocked subsequently. They should be stocked in only small lakes with very heavy angling pressure or in two story lakes. Brown trout should also not be stocked in sections of stream where natural brook trout populations are significant, because, in most instances, brook trout populations will be displaced by brown trout.

WRIGHT, B. H. and R. D. SOPUCK. 1979. A history of fish stocking in Northern Manitoba. Fisheries Research Manuscript Report 79-6. Manitoba Department of Mines, Natural Resources and Environment. Winnipeg, Manitoba. 70 p.

Although there has been extensive stocking of rainbow and brook trout, the stocking of brown trout in northern Manitoba has been rare in recent history. Borrow Pit on Highway 10 was stocked with 300 two-year old brown trout in 1974. Successful overwintering does occur, yet this was considered a one-year put-and-take fishery. This particular borrow pit was considered a success as it provided non-native trout fishing recreation for tourists and local anglers.

WYDOSKI, R. S. 1986. Informational needs to improve stocking as a cold-water fisheries management tool. p. 41-57. *In* R. H. Stroud [ed.]. Fish Culture in Fisheries Management: Proceedings of a Symposium on the role of Fish Culture and Fisheries Management, March 31-April 3, 1985, Lake Ozark, Montana.

The stocking of cold-water fish in North America began well over 100 years ago, with the hope of restoring populations of important food fish that declined during the late 1700s and early 1800s. Claimed early successes of stocking and its appearance of being a logical approach in restoring fisheries led the public, as well as state and federal governments, to believe that stocking was the panacea for increasing abundance of fish. Early biologists held hatcheries in low esteem, however, because they could readily identify numerous instances where the wrong species had been stocked in the wrong places, under the wrong conditions.

Today, it is known that the management of a fishery depends on numerous interacting factors associated with fish, fish habitat, and people. Because these factors are now better understood, fisheries biologists are working closely with fish culturists to ensure that hatcheries play an important and effective role in fisheries management.

This paper provides an overview of stocking as a management tool to create, enhance, or restore cold-water fisheries.

ZALEWSKI, M., P. FRANKIEWICZ and B. BREWINSKA. 1985. The factors limiting growth and survival of brown trout (*Salmo trutta fario*) introduced to different types of streams. Journal of Fish Biology 27 (Supplement A) : 59-73.

Fingerlings of brown trout (*Salmo trutta fario*) were introduced to sections of different types of streams situated in natural catchments and those modified by Man's activity. At stations where environmental conditions were modified by such forms of impact as pollution, flow variability and impoundment, trout did not survive five months. In the natural river sections mortality rates increased downstream along the river continuum and were associated with increased predation. Growth rates in the upper reaches were primarily restricted by abiotic factors – temperature and trophic status: however, they were to a large extent modified by density-dependent regulation and intraspecific competition. The influence of the abiotic/biotic regulatory process, expressed as fish metabolic performance, is discussed as a framework for the determination of the carrying capacity of the riverine ecosystem.

ZALEWSKI, M., P. FRANKIEWICZ and B. BREWINSKA-ZARAS. 1986. The production of brown trout (*Salmo trutta*) introduced to streams of various orders in an upland watershed. Polskie Archiwum Hydrobiologii 33(3-4) : 411-422.

Acknowledgements

Numerous people were involved in the compilation of information for this publication. We are indebted Margaret Wells and Elizabeth Gustafsson, of the Ontario Ministry of Natural Resources library in Peterborough, who aided in library searches. We are grateful to the OMNR biologists and field staff, as well as those from other Provincial and State agencies who contributed data to this publication.

Wendy Stott provided historical stocking information. Ola McNeil and Scott Watson provided information regarding stocking from Ontario provincial hatcheries. Judy Gibbens and Tracy Allison provided access to information at Trent University.

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1.0 General References

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1.2 Reports of Stocking Projects

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Barton and McNeil (1981)
Beaudou, Robert De and Berrebi (1994)
Borgeson (1987)
Cowx (1994)
Cresswell (1989)
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Fitch (1977)
Heidinger (1993)
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Wydoski (1986)

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Anonymous (1953)
Cooper (1952)
Cresswell et al. (1982)

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- Cresswell and Williams (1982)
- Hofman (1989)
- Jokikokko (1999)
- Jonssonn et al. (1999)
- Klein (1975)
- L'Abee-Lund and Langeland (1995)
- Larsen (1972)
- Marshall and Menzel (1984)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_b$)
- Shetter (1944)
- Shetter and Hazzard (1940)

2.3 Time of Stocking

- Aass (1984)
- Ahronen and Ikonen (1993)
- Anonymous (1953) (1965)
- Barker (1955)
- Boles and Borgenson (1966)
- Brynildson (1967)
- Brynildson et al. (1963) (1966)
- Chamberlain (1943)
- Christenson et al. (1954)
- Cresswell (1981)
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- Degan (1986)
- Dexter (1991)
- Fitch (1977)
- Hale (1950)
- Hale and Smith (1955)
- Hale and Gray (1998)
- Hesthagen and Johnsen (1989$_b$)
- Hofman (1989)
- Johnsen and Ugedal (1986) (1989)
- Johnson et al. (1998)
- Johnson and Hiner (1947)
- Kennedy (1982)
- Kennedy et al. (1984)
- Kuehn and Schumacher (1957)
- Maine Fisheries Research and Management Section (2000)
- Mullan and Tompkins (1959)
- Naesland (1992) (1993)
- Nesbit and Kitson (1937)
- O'Grady (1982) (1983)
- Owens and Bettoli (1998)
- Pederson and Rasmussen (2000)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_a$)
- Schumacher (1958)
- Shetter (1944) (1962)
- Strange and Kennedy (1979)
- Templeton (1971)
- Trembley (1943)
- Trzebiatowski (1993)
- Wierich (1974)
- Wilde (1956)

2.4 Stocking Rates

- Anonymous (1954)
- Biagi and Martin (1992)
- Butler (1975)
- Cooper (1952)
- Hesthagen and Johnsen (1992)
- Kelly (1965)
- Kelly-Quinn and Bracken (1989$_a$)
- Maine Fisheries Research and Management Section (2000)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988$_a$) (1988$_b$)
- Rasmussen and Geertz-Hansen (1998)
- Saura et al. (1990)
- Shetter and Hazzard (1940)
- Vehanen (1995)
- Wahab et al. (1989)

2.5 Age/Size of Fish

- Aass (1978)
- Ahvonen and Ikonen (1993)
- Alexander (1985)
- Anonymous (1953) (1954)
- Bagenal (1969)
- Barker (1955)
- Bartel (1988)
- Berg and Jorgensen (1991)
- Boles (1960)
- Boles and Borgenson (1966)
- Borawa (1990)
- Brynildson (1967)
- Brynildson and Kempinger (1973)
- Cresswell (1981)
- Crisp (1996)
- Curtis (1951)
- Damsgaard and Langeland (1994)
- Debowski et al. (1992)

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- Degan (1980)
- Dexter (1991)
- Eipper (1963)
- Fajfer and Belonger (1997)
- Ferguson (1983)
- Fitch (1977)
- Frankenberger (1969)
- Hale (1950) (1952_b)
- Hale and Smith (1955)
- Hale and Gray (1998)
- Hartlzer (1977)
- Heggenes (1988)
- Helfrich and Kendall (1982)
- Hesthagen et al. (1999)
- Hesthagen and Hegge (1992)
- Hesthagen and Johnsen (1989_b) (1992)
- Holloway and Chamberlain (1942)
- Hulbert (1985)
- Johnsen and Hesthagen (1990)
- Johnsen and Ugedal (1988)
- Johnson and Hiner (1947)
- Jorgensen and Berg (1991)
- Kelly-Quinn and Bracken (1989_a)
- Kennedy (1982)
- Kirkland and Bowling (1966)
- Kruger and May (1991)
- Louder (1969)
- Maine Fisheries Research and Management Section (2000)
- Mullan (1956)
- Mullan and Tompkins (1959)
- Naeslund (1990) (1998)
- Needham (1969)
- Needham and Slater (1944)
- Nihouarn et al. (1990)
- O'Grady (1982)
- Pederson and Rasmussen (2000)
- Pirhonen et al. (1998)
- Preston (1965)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988_a)
- Rasmussen (1984)
- Saura et al. (1990)
- Schumacher (1954)
- Shetter and Hazzard (1940)
- Skurdal et al. (1989)
- Swartz (1950)
- Taggart and Ferguson (1986)
- Takkunen (1993)
- Toivonen et al. (1994)
- Trzebiatowski (1993)
- Vehanen (1995) (1997)
- Weber (1988)
- Weiss and Schmutz (1999_b)
- Wilde (1956)
- Zalewski et al. (1985)

2.6 Marking Techniques
- Aass (1990_a)
- Archer (1967)
- Barker (1955)
- Bartel (1987)
- Bohm and Bettoli (1997)
- Brewin et al. (1995)
- Chamberlain (1943)
- Cobb (1933)
- Cooper (1953)
- Damsgard and Langeland (1994)
- Devlin and Bettoli (1998)
- Dexter (1991)
- Fajfer and Belonger (1997)
- Hale (1952_b)
- Hale and Gray (1998)
- Hambly (1968)
- Herman (1997)
- Hesthagen and Hegge (1992)
- Johnsen and Ugedal (1988)
- Johnstone et al. (1995)
- Jonssonn et al. (1999)
- Kelly (1965)
- Kennedy et al. (1982)
- Loeb (1964) (1968)
- Luisi and Bettoli (2000)
- Malhiot (1999)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988_a)
- Needham (1959)
- Nemeth and Bettoli (1998)
- Niva and Juntunen (1993)
- North (1983)
- Nuhfer et al. (1996)
- O'Grady (1984_a)
- Owens and Bettoli (1998)
- Schumacher (1954)
- Shetter (1944) (1962)
- Smith and Smith (1943)
- Strange and Kennedy (1982)
- Templeton (1971)
- Timmerman (1999)
- Toivonen et al. (1994)
- Trembley (1943)

2.6 Marking Techniques (cont'd)
- Weber (1988)
- Weiss and Schmutz (1999_a)

2.7 Diseases and Parasites of Fish
- Anonymous (1982) (1983) (1999_a)
- Dewald and Wilzbach (1992)
- Eckert (1982)
- Haunschmid and Kozak (1997)
- Hosmer (1980)
- Hulbert (1985)
- Kernen (1969)
- Kerr and Grant (2000)
- Rahkonen and Koski (1997)
- Richards and Pickering (1978)
- Rintamaeki-Kinnunen and Tellervo Valtonen (1997)
- Thorpe et al. (1947)

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- Avery (1975)
- Bettross (2000)
- Cortes (1996)
- Garman and Nielsen (1982)
- Hart (1990)
- Niva (1996_b)
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2.9 Transport and Release Techniques
- Barton (2000)
- Johnsen and Hesthagen (1990)
- Luton (1985)
- Miller (1958)
- Nikinmaa et al. (1983)
- Quillet et al. (1986)

2.10 Stocking Site
- Ahronen and Ikonen (1993)
- Bartel (1988)
- Cadwallader (1983)
- Fitch (1977)
- Fjellheim et al. (1995)
- Hale and Gray (1998)
- Hofman (1989)
- Johnsen and Hesthagen (1996)
- Jonsson et al. (1994) (1995)
- Klein (1975)
- Larsson et al. (1979)
- Lorz (1974)
- Maine Fisheries Research and Management Section (2000)
- Mason and Wegner (1970)
- Québec Ministère du Loisir, de la Chasse et de la Pêche (1988_a) (1988_b)
- Rasmussen and Geertz-Hansen (1998)
- Schuck and Kingsbury (1948)

2.11 Genetic Strain
- Aass (1990_a) (1990_b) (1990_d) (1993)
- Alexander (1985)
- Alexander and Nuhfer (1993)
- Anonymous (1998)
- Arias et al. (1995)
- Barbat-Leterrier et al. (1989)
- Barwick and Geddings (1985)
- Berg and Jorgensen (1991)
- Berrebi et al. (2000)
- Boles (1960)
- Boles and Borgenson (1966)
- Borawa (1988) (1990)
- Crawford (1997)
- Fajfer and Belonger (1997)
- Ferguson et al. (1991)
- Garcia-Marin et al. (1991)
- Hansen et al. (1995)
- Heacox (1937)
- Hofman (1989)
- Holcomb (1964)
- Hulbert (1985)
- Johnsson et al. (1996)
- Kelley-Quinn and Bracken (1989_b)
- Krieg and Gyuomard (1985)
- Krueger et al. (1986)
- Krueger and May (1987)
- L'Abee-Lund and Langeland (1995)
- L'Abee-Lund and Sægrov (1992)
- Larsson et al. (1979)
- Lavgiader and Scholl (1995)
- Machordom et al. (1999)
- Maisse et al. (1983)
- Mansell (1966)
- Martinez (1993)
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- Moran et al. (1989)
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Nuhfer (1996)
O'Grady (1982) (1984$_b$)
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Pirhonen et al. (1998)
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Ryman and Ståhl (1980)
Schluntz et al. (1999)
Shelby (1917)
Skrochwska (1969)
Staley (1966)
Weiss and Kummer (1999)
Weiss and Schmutz (1999$_a$)
Wisconsin Bureau of Fisheries Management and Habitat Protection (1999)

2.12 Physical/Chemical Requirements of Stocked Waters
Anonymous (1930)
Barlaup and Åtland (1994)
Barlaup et al. (1996)
Bettross (2000)
Cresswell and Williams (1979)
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Goodman (1991)
Goudreau (1998)
Grande and Andersen (1990)
Hermansen and Krog (1990)
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Oatis (1970)
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Pyle and Soldwedel (1973)
Quillet et al. (1986)
Raddum et al. (1986)
Scullion and Edwards (1979)
Toivonen et al. (1994)
Ugedal et al. (1998)
Vehanen (1995)

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Aass (1990$_d$)
Alexander (1970)
Ahronen and Ikonen (1993)
Archer (1967)
Arias et al. (1995)
Barker (1955)
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Brynildson (1957)
California Department of Fish and Game (1960)
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Kelley (1953) (1965)
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Valkeajarvi (1993)
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Wiggins (1950)
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Wright and Sopuck (1979)
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- Bartel et al. (1988)
- Berregi et al. (2000)
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- Hambly (1968)
- Hart (1990)
- Hill and Platts (1998)
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- Ikonen and Auvinen (1982)
- Johnsen and Hesthagen (1990)
- Kerr (1983) (1984)
- Kerr et al. (1990)
- Kolari and Ikonen (1989)
- Kosa (1999)
- Larsen (1959)
- Lemmien et al. (1957)
- Malhiot (1999)
- Mutenia and Salonen (1992)
- Nemeth and Bettoli (1998)
- Nihouarn et al. (1990)
- Niva and Juntunen (1993)
- O'Donnell (1996)
- Schumacher (1958)
- Smith (1948)
- Thorpe et al. (1947)
- Timmerman (1999)
- Wales (1946)
- Welsh Water Authority (1986)

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- Aass (1984)
- Alexander (1985)
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- Millard (1971)
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- Wisconsin Department of Natural Resources (1980)
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- Hulbert (1985)
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- Johnson and Hiner (1947)
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- Klolari and Ikonen (1989)
- Kosa (1999)
- Kuehn and Schumacher (1957)
- L'Abee-Lund and Sægrov (1991)
- Louder (1969)
- Mansell (1966)
- McCaig et al. (1960)
- Millard (1971)
- Millard and MacCrimmon (1972)
- Mill and Ryan (1973)
- Mulan and Tompkins (1959)
- Needham (1954)
- Nielsen et al. (1980)
- North (1983)
- Nuhfer et al. (1996)
- Ontario Ministry of Natural Resources (1999)
- Peck (1992)
- Ratledge (1966)
- Schumacher (1954) (1958)
- Scullion and Edwards (1979)
- Shetter (1944) (1962)
- Shetter and Hazzard (1940)
- Skurdal et al. (1989)
- Smith and Smith (1943)
- Strange and Kennedy (1979)
- Swartz (1950)
- Taylor (1978)

3.4 Returns to the Fishery (cont'd)

- Thorpe et al. (1947)
- Trembley (1943)
- Vehanen (1995)
- Vehanen, Hyvarinen and Aspi (1998)
- Vestal (1954)
- Wales (1946)
- Weber (1988)
- Wisconsin Department of Natural Resources (1980)

3.5 Physiology and Morphology of Stocked Fish

- Aarestrup et al. (2000)
- Anonymous (1999_b)
- Barton (2000)
- Johnsson et al. (1996)
- Nielsen et al. (1999)
- Niva (1996_b)
- Pirhonen and Forsman (1999)
- Sosiak (1982)
- Sundell et al. (1998)
- Welsh Water Authority (1986)

3.6 Behaviour of Stocked Fish

- Aitken and Surber (1932)
- Avery (1978)
- Bachman (1984)
- Brynildson et al. (1963)
- Buss and McCreary (1960)
- Deverill et al. (1999)
- DeWald and Wilzbach (1992)
- Hesthagen and Hegge (1992)
- Hesthagen and Johnsen (1989_a)
- Hulbert and Engstrom-Heg (1982)
- Johnsson et al. (1996)
- Kernen (1969)
- Lucas (1993)
- McLaren (1979)
- McLeish (1984)
- Miller (1958)
- Petersson and Järvi (2000)
- Thorfve and Carstein (1998)
- Zalewski et al. (1985)

3.7 Growth of Stocked Fish

- Aass (1978)
- Alexander (1985)
- Alexander and Nuhfer (1993)
- Anonymous (1998)
- Barlaup and Åtland (1994)
- Bartell (1987)
- Biagi and Martin (1992)
- Bohm and Bettoli (1997)
- Boles and Borgenson (1966)
- Borawa (1988)
- Brynildson and Christenson (1961)
- Brynildson and Kempinger (1973)
- Brynildson et al. (1966)
- Burrough and Kennedy (1978_b)
- Buss and McCreary (1960)
- Butler (1975)
- Coles (1981)
- Crisp (1996)
- Debowski et al. (1992)
- Degan (1980)
- Deverill et al. (1992)
- Devlin and Bettoli (1998)
- DeWald and Wilzbach (1992)
- Eckert (1982)
- Eipper (1953)
- Fajfer and Belonger (1997)
- Fjellheim et al. (1995)
- Garman and Nielsen (1982)
- Glenn et al. (1989)
- Goudreau (1998)
- Hale (1952_b)
- Hesthagen and Johnsen (1989_b) (1992)
- Hesthagen et al. (1999)
- Johnsen and Ugedal (1988)
- Johnsson et al. (1996)
- Jonsson et al. (1995)
- Jonssonn et al (1999)
- Kirkland and Bowling (1966)
- Kolari and Ikonen (1989)
- L'Abee-Lund and Sægrov (1991)
- Larsson et al. (1979)
- Loeb (1968)
- Luisi and Bettoli (2000)
- Maisse et al. (1983)
- Marconato et al. (1990)
- Marshall and Menzel (1984)
- Mason and Wegner (1970)
- Naeslund (1990) (1993)
- Nesbit and Kitson (1937)
- Nuhfer (1996)
- O'Grady (1984_a)
- Owens and Bettoli (1998)
- Petersson and Järvi (2000)
- Pirhonen et al. (1998)
- Raddum et al. (1986)
- Saura et al. (1990)
- Schuck and Kingsbury (1948)
- Smith and Smith (1943)

3.7 Growth of Stocked Fish (cont'd)

- Trembley (1943)
- Valkeajarvi (1993)
- Wales (1946)
- Weiss and Schmutz (1999_b)

3.8 Movements of Stocked Fish

- Aarestrup et al. (2000)
- Aitken and Surber (1932)
- Bartel (1987)
- Brynildson (1967)
- Cobb (1933)
- Cresswell (1981)
- Cresswell and Williams (1979) (1982) (1983) (1984)
- Cresswell et al. (1982)
- Crisp (1996)
- Devlin and Bettoli (1998)
- Fjellheim et al. (1995)
- Helfrich and Kendall (1982)
- Hulbert and Engstrom-Heg (1982)
- Johnstone et al. (1995)
- Jonsson et al. (1994) (1995)
- Jonssonn et al. (1999)
- Jorgensen and Berg (1991)
- Kennedy (1982)
- Kernen (1969)
- Kosa (1999)
- Marconato et al. (1990)
- McLeish (1984)
- Mill and Ryan (1973)
- Naeslund (1990) (1992) (1993) (1998)
- Nettle et al. (1987)
- Pirhonen et al. (1998)
- Ruhle (1983)
- Schulz (1999)
- Scullion and Edwards (1979)
- Skrochwska (1969)
- Skurdal et al. (1989)
- Templeton (1970_a) (1970_b)
- Thorfve and Carstein (1998)
- Trembley (1943)
- Ugedal et al. (1998)
- Valkeajarvi (1993)
- Vehanen, Hyvarinen and Aspi (1998)
- Weiss and Kummer (1999)
- Wierich (1974)

3.9 Food Habits of Stocked Fish

- Aitken and Surber (1932)
- Aass (1990_a)
- Avery (1978)
- Bachman (1984)
- Boles (1960)
- Brynildson and Kempinger (1973)
- Burrough and Kennedy (1978_b)
- Cresswell et al. (1982)
- Crisp (1990)
- Cooper et al. (1992)
- Damsgaard (1995)
- Damsgaard and Langeland (1994)
- De Rocha and Mill (1984)
- Garman and Nielsen (1982)
- Hesthagen and Johnsen (1989_a)
- Hesthagen et al. (1995)
- Johnsen and Ugedal (1986) (1989) (1990)
- Kelly-Quinn and Bracken (1989_b)
- Kerr and Grant (2000)
- Kirkland and Bowling (1966)
- Krueger and May (1991)
- L'Abee-Lund and Langeland (1995)
- L'Abee-Lund and Sægrov (1991) (1992)
- L'Abee-Lund et al. (1992)
- Lachner and Raney (1941)
- Lucas (1993)
- MacKay (undated)
- Maisse et al. (1983)
- McCoy (1974)
- Niva (1999_a) (1999_b)
- O'Gorman et al. (1987)
- O'Grady (1983)
- Pirhonen et al. (1998)
- Rahkonen and Koski (1997)
- Stensen and Svensson (1994)
- Thorfve and Carstein (1998)
- Toivonen et al. (1994)
- Vehanen (1995)
- Vehanen, Hyvarinen and Huusko (1998)
- Wahab et al. (1989)
- Wales (1946)
- Webster and Little (1944)

3.10 Reproduction of Stocked Fish

- Aass (1993)
- Banks and Bettoli (1999)
- Barlaup et al. (1996)
- Boles (1960)
- Bouvet and Chacormac (1986)
- Cooper et al. (1992)
- Curtis (1951)

3.10 Reproduction of Stocked Fish (cont'd)

Fajfer and Belonger (1997)
Johri and Prasad (1989)
Jokikokko (1990)
Kernen (1969)
O'Grady (1984$_b$)
Preston (1965)
Saura et al. (1990)
Stefanik and Sandheinrich (1999)

3.11 Hybridization of Stocked Fish

Arias et al. (1993)
Barbat-Leterrier et al. (1989)
Beaudou, Cattaneo-Berrebi and Berrebi (1994)
Berrebi et al. (2000)
Blanco et al. (1996) (1998)
Budihna and Ocvirk (1990)
Cagigas et al. (1999)
Garcia-Marin et al. (1991) (1998) (1999)
Guyomard and Krieg (1986)
Guyomard et al. (1997)
Hansen et al. (1995) (2000)
Hauser et al. (1991)
Krieg and Guyomard (1985)
Krueger and May (1991)
Largiader and Scholl (1995) (1996)
Largiader et al. (1996)
Linløkken et al. (1999)
Machordom et al. (1999)
Martinez et al. (1993)
Palm and Ryman (1999)
Poteaux et al. (1997) (1998) (1999)
Scheerer et al. (1987)
Skaala et al. (1996)
Skrochwska (1969)
Staley (1966)
Taggart and Ferguson (1986)

3.12 Impacts of Stocked Fish

Anonymous (undated$_a$)
Ault and White (1994)
Aurelle et al. (1999)
Borawa (1988)
Brooks (2000)
Brynildson et al. (1963)
Burrough and Kennedy (1978$_a$) (1978$_b$)
Christie et al. (1972)
Cortes (1996)
Damsgaard (1995)
Damsgaard and Langeland (1994)
Davies et al. (1988)
DeWald and Wilzbach (1992)
Dexter (1991)
Garman (1980)
Garman and Nielsen (1982)
Goodman (1991)
Hansen and Loeschcke (1994)
Haunschmid and Kozak (1997)
Krueger and May (1991)
Larsen (1959)
MacKay (undated) (1957)
Mansell (1966)
McDowall (1968)
McIntosh et al. (1992)
Millard (1971)
Millard and MacCrimmon (1972)
Nelson (1965)
O'Gorman et al. (1987)
Staley (1966)
Stenson and Svensson (1994)
Townsend and Crowl (1991)
Vermount Department of Fish and Wildlife (1993)
Wahab et al. (1989)
Weiss and Schmutz (1999$_b$)
Welcomme (1988)

3.13 Susceptibility to Predators

Brynildson et al. (1963)
Buss and McCreary (1960)
Cresswell et al. (1982)
Dieperink (1995)
Greenberg (1992)
Hesthagen and Johnsen (1989$_a$) (1992)
Johnson et al. (1998)
Johnsson et al. (1996)
Kennedy (1982)
Klein (1975)
MacKay (1957)
Marshall and Johnson (1971)
Vehanen (1995)

3.14 Stocking Economics

Aass (1984) (1990$_b$)
Alexander (1985)
Alexander and Nuhfer (1993)
Butler (1975)
Christenson et al. (1954)
Dexter (1991)
Frankenberger (1969)

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3.14 Stocking Economics (cont'd)
- Hale and Smith (1955)
- Kennedy et al. (1984)
- Marshall and Menzel (1984)
- Nesbit and Kitson (1937)
- Vestal (1954)
- Wales (1946)

3.15 Health and Condition Factor of Stocked Fish
- Arias et al. (1995)
- Barlaup and Åtland (1994)
- Borawa (1988)
- Bouvet and Chacormac (1986)
- Brynildson and Christenson (1961)
- Cooper and Benson (1951)
- Cresswell et al. (1982)
- Damsgaard and Langeland (1994)
- Devlin and Bettoli (1998)
- Haunschnid and Kozak (1997)
- Naeslund (1998)
- Nicholls (1958)
- Pirhonen et al. (1998)
- Sundell et al. (1998)

3.16 Effects of Handling and Acclimatization Time on Stocked Fish
- Cresswell and Williams (1983)
- Hosmer (1980)
- Johnson et al. (1998)
- Jonsson et al. (1994)
- Jonssonn et al. (1999)
- Kennedy (1982)
- L'Abee-Lund and Langeland (1995)
- Nikinmaa et al. (1983)
- Pederson and Rasmussen (2000)

3.17 Habitat Preference/Spatial Distribution of Stocked Fish
- Cresswell (1981)
- Cresswell and Williams (1984)
- DeWald and Wilzbach (1992)
- Greenberg (1992_b)
- Heggenes (1988)
- Helfrich and Kendall (1982)
- Hermansen and Krog (1984)
- Hesthagen et al. (1995)
- Johnstone et al. (1995)
- Jutila et al. (1999)
- Kirkland and Bowling (1966)
- L'Abee-Lund and Langeland (1995)
- L'Abee-Lund and Sægrov (1991)
- L'Abee-Lund et al. (1992)
- Marshall and Menzel (1984)
- McIntosh et al. (1992)
- McLaren (1979)
- Sosiak (1982)

3.18 Homing of Stocked Fish
- Debowski and Bartel (1995)
- Ruhle (1983)
- Scholz et al. (1978)

APPENDIX 1. Brown trout stocking in Ontario waters, 1900-2000. Information was obtained through Federal and Provincial Annual Fisheries Reports (1900-1989), OFIS database (1990-1994) and Provincial Fish Culture Stations (1995-2000).

	Life Stage Stocked							
Year	Eyed Eggs	Fry	Fingerlings	Yearlings	Sub-Adults	Adults	Unknown	Total
1900	-	-	-	-	-	-	-	-
1901	-	-	-	-	-	-	-	-
1902	-	-	-	-	-	-	-	-
1903	-	-	-	-	-	-	-	-
1904	-	-	-	-	-	-	-	-
1905	-	-	-	-	-	-	-	-
1906	-	-	-	-	-	-	-	-
1907	-	-	-	-	-	-	-	-
1908	-	-	-	-	-	-	-	-
1909	-	-	-	-	-	-	-	-
1910	-	-	-	-	-	-	-	-
1911	-	-	-	-	-	-	-	-
1912	-	-	-	-	-	-	-	-
1913	-	-	-	-	-	-	3,000	3,000
1914	-	-	-	-	-	-	2,300	2,300
1915	-	-	-	-	-	-	25,000	25,000
1916	-	-	-	-	-	-	-	-
1917	-	-	-	-	-	-	-	-
1918	-	-	-	-	-	-	44,000	44,000
1919	-	-	-	-	-	-	-	-
1920	-	-	-	-	-	-	-	-
1921	-	-	-	-	-	-	-	-
1922	-	-	-	-	-	-	-	-
1923	-	-	-	-	-	-	-	-
1924	-	-	-	-	-	-	-	-
1925	-	-	-	-	-	-	-	-
1926	-	-	-	-	-	-	-	-
1927	-	-	-	-	-	-	-	-
1928	-	-	-	-	-	-	-	-
1929	-	-	-	-	-	2,590	-	2,590
1930	-	-	70,500	-	-	-	-	70,500
1931	-	-	900,600	-	-	-	-	900,600
1932	-	-	628,060	1,100	-	-	-	629,160
1933	-	-	483,016	674	-	-	-	483,690
1934	-	-	138,000	14,500	-	689	-	153,189
1935	-	-	109,000	9,650	-	6	-	118,656
1936	-	-	147,050	7,290	-	-	-	154,340
1937	-	-	-	97,848	-	-	-	97,848
1938	-	-	-	59,592*	-	-	-	59,592
1939	-	-	29,954	375,070	-	-	-	405,024
1940	-	-	182,785	252,000	-	-	-	434,785
1941	-	-	60,000	346,188	-	-	-	406,188
1942	-	-	23,000	359,275	-	-	-	382,275
1943	10,000	-	1,000	303,335	-	-	-	314,335
1944	-	-	-	330,250	-	-	-	330,250
1945	5,000	-	-	224,729	-	-	-	229,729
1946	-	-	133,025	268,940	-	-	-	401,965
1947	-	-	-	375,850	-	-	-	375,850

Year	Eyed Eggs	Fry	Fingerlings	Yearlings	Sub-Adults	Adults	Unknown	Total
1948	-	9,000	557,505	350,113	-	-	-	916,618
1949	-	10,000	175,000	221,800	-	-	-	406,800
1950	-	10,000	307,000	85,475	-	-	-	402,475
1951	-	-	282,700	54,900	-	-	-	337,600
1952	-	-	107,500	140,400	-	-	-	247,900
1953	-	-	92,000	103,100	-	-	-	195,100
1954	-	-	100,000	177,950	-	-	-	277,950
1955	-	-	100,800	233,800	-	220	-	334,820
1956	-	-	29,100	150,550	-	50	-	179,700
1957	8,000	-	36,000	169,650	-	-	-	213,650
1958	-	-	21,800	132,926	-	235	-	154,961
1959	-	-	-	192,795	-	12	-	192,807
1960	-	-	1,700	85,380	-	79	-	87,159
1961	-	-	640	5,000	-	-	-	5,640
1962	-	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	-	-
1964	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	-
1968	-	-	-	-	-	-	-	-
1969	-	-	-	14,957	-	-	-	14,957
1970	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	71,150	71,150
1983	-	-	-	-	-	-	134,271	134,271
1984	-	-	-	-	-	-	165,047	165,047
1985	-	-	-	-	-	-	166,000	166,000
1986	-	-	-	-	-	-	305,000	305,000
1987	-	-	-	-	-	-	397,000	397,000
1988	-	-	-	-	-	-	520,000	520,000
1989	-	-	-	-	-	-	536,000	536,000
1990	-	-	62,351	73,320	-	-	-	135,671
1991	-	-	114,194	63,067	-	-	-	177,261
1992	-	-	35,499	475,636	1048	721	-	512,904
1993	-	-	31,859	332,415	-	391	1867	366,532
1994	-	-	35,000	471,361	14,286	850	-	521,497
1995	-	-	17,232	316,594	-	-	-	333,826
1996	-	-	136,777	259,256	-	-	-	396,033
1997	-	-	84,503	234,292	-	-	-	318,795
1998	-	-	77,162	230,962	-	2,489	-	310,613
1999	-	-	31,943	269,519	-	2,476	-	303,936
2000	-	-	-	284,540	-	-	-	284,541

*yearlings and adults

**eggs and fry

APPENDIX 2. A summary of post-stocking survival rates of brown trout reported from various waters.

Waterbody	Life Stage/Size Stocked	Time from Release	Survival Rate (%)	Reference
Creeks/Streams				
Black Earth Creek (Wisconsin)	Fingerlings	~6 months ~2.5-3.5 months ~10.5 months	51-90% (over four years) 13% 7%	Bryniildson et al. (1966)
Deer Creek (Ontario)	Fry	~5 months	14.4%	Ferguson (1983)
Convict Creek (California)	Fingerlings	1 year	63.7% (5 year average)	Needham and Slater (1944)
Owendoher Stream (Ireland)	Fry	3 weeks	<33%	Kelly-Quinn and Bracken (1989)
Unnamed Stream (tributary to Lake Constance)	Unknown	1 year	12.3% (lake strain) 12.1% (resident strain)	Schulz (1999)
Unnamed Stream (Austria)	Adult	1 month 8 months	86% 14%	Weiss and Schmutz (1999$_a$)
Unnamed Stream (Austria)	Fingerlings (>179-199 mm)	3 months	80% (average)	Weiss and Schmutz (1999$_b$)
Unnamed Stream (Austria)	Fingerlings (>179-199 mm)	3 months	55% (average)	Weiss and Schmutz (1999$_b$)
13 unnamed streams (Wisconsin)	Yearlings	60-120 days	11.3% (average)	Johnson (1983)
Unnamed Streams (Norway)	Fingerlings	1 year	29.2%	Johnsen and Ugedal (1988)
Watson Creek (Minnesota)	4.7-12.7"	6.5 months 9 months 11.75 months	42.8% 7.6% 3.6%	Hale and Smith (1955)
Lakes				
Nebish Lake (Wisconsin)	Fingerlings	5.5 months	0%	Avery (1975)
2 Unnamed lakes (Northern Ireland)	Fingerlings	~6 months	31.0% 15.2%	Kennedy et al. (1984)
4 Unnamed lakes (Manitoba)	Fingerlings	138-162 days	~44.0%	Glenn et al. (1989)

Waterbody	Life Stage/Size Stocked	Time from Release	Survival Rate (%)	Reference
Ponds				
20 Farm Dugouts (Manitoba)	Fingerlings	139-146 days	~30.0%	Glenn et al. (1989)
Unnamed Pond (Norway)	Fingerlings	5-10 days 5-10 days	93.1% 90.8%	Hesthagen and Hegge (1992)
Rivers				
Lower Willow River (Wisconsin)	Fingerlings	~6 months	20-26.3% 11.6-40.1% (three year averages)	Frankenberger (1969)
North Esk River (Australia)	Yearlings	8-9 months 18 months ~2 years	10.0% <5.0% ~2.0%	Nicholls (1958)
Pigeon River (Michigan)	Fingerlings	1 year	23.0%	Cooper (1953)
Sydenham River (Ontario)	Yearlings	~5 months	26.0%	Millard (1971)
Teigdal River (Norway)	Fingerlings	10 months	1.0%	Fjellheim et al. (1995)
Other				
Earthen Raceway	Fingerlings	1 year	23.0%	Buss and McCreary (1960)

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APPENDIX 3. Contributions of stocked brown trout to selected recreational fisheries in various waters.

Waterbody	Life Stage/Size Stocked	Time from Release	Recapture Rate (% of number stocked)	Reference
Creeks/Streams				
August Creek (Michigan)	Yearlings	200 days	3.3-13.2% and 2.8-8.2% of number stocked	Dexter (1991)
(Main) Au Sable Creek (Michigan)	Catchables	~10 months ~5 months	7.2% 12.8%	Shetter (1944)
Baldwin Creek (Michigan)	Catchables	~10 months ~5 months	7.2% 6.4%	Shetter (1944)
Clear Creek (Wyoming)	8"	1 year	4.7%	Anonymous (1954)
Dowagiac Creek (Michigan)	Catchables	~10 months ~5 months	0% 4.0%	Shetter (1944)
Dusche Creek (Minnesota)	Catchables	10 months	21.7%	Smith and Smith (1943)
Dusche Creek (Minnesota)	Yearlings	3.5-4.5 months	23.6%	Schumacher (1954)
Dusche Creek (Minnesota)	Yearlings	~10 months ~5 months	51.4% 68.3%	Schumacher (1958)
Gamble Creek (Michigan)	Fingerlings	Unknown	0.1%	Anonymous (1953)
Portage Creek (Michigan)	Catchables	~10 months ~5 months	0.0% 12.8%	Shetter (1944)
Spring Creek (Pennsylvania)	Catchables	~7.5 months ~7 months ~4 months	54.8% 54.3% 46.7%	Trembley (1943)
Unnamed Streams (Massachusetts)	6-8" 8-9" 9-12"	1 month	15.0% 17.0% 32.0%	Mullan (1956)
Lakes				
Castle Lake (California)	Fingerlings Yearlings	5 year average	4.8% 32%	Curtis (1951)
Frog Lake (California)	Fingerlings	7 year average	7.7%	Curtis (1951)
Lower Sardine Lake (California)	Catchables	6 years	46.0%	Boles (1960)

Waterbody	Life Stage/Size Stocked	Time from Release	Recapture Rate (% of number stocked)	Reference
Oslofjord (inner) (Norway)	1 and 2 year olds	Unknown	12.1%	Jonsson et al. (1995)
Oslofjord (outer) (Norway)	1 and 2 year olds	Unknown	16.8%	Jonsson et al. (1995)
2 Unnamed lakes (Northern Ireland)	Fingerlings	~2 years	9.3%	Strange and Kennedy (1979)
		~2 years	1.3%	
Ponds				
Big Spectacle Pond (Massachusetts)	6-10"	~ 5 months	2.2%	Nesbit and Kitson (1937)
		~10 months	1.1%	
Unnamed ponds (Massachusetts)	Unknown	Unknown	13.6%	Mullan and Tompkins (1959)
			53%	
			2%	
			42%	
Reservoirs				
Canyon Reservoir (Texas)	Fingerlings	~ 3 years	<1.0%	Butler (1975)
Draycote Water (Great Britain)	Catchables	~45 days	42.2%	North (1983)
Quabbin Reservoir (Massachusetts)	9-12"	1 year	23.0%	McCaig et al. (1960)
		2 years	10.0%	
		1 year	2.4%	
Rivers				
River Akerselva (Norway)	1 and 2 year olds	Unknown	20.3%	Jonsson et al. (1995)
Farmington River (Massachusetts)	6-10"	~5 months	9.1%	Nesbit and Kitson (1937)
		~10 months	3.1%	
Lågen and Otta rivers (Norway)	Catchables	1 year	22.8%	Skurdal et al. (1989)
		1 year	41.6%	
		2 years	5.9%	
		1 year	58.0%	
		2 years	2.0%	
		1 year	49.5%	
		2 years	3.1%	
		3 years	1.0%	
		1 year	48.0%	
		2 years	1.0%	
		1 year	44.1%	
Little Manistee River (Michigan)	Catchables	~5 months	19.2%	Shetter and Hazzard (1940)
		~ 4 months	15.2%	

Waterbody	Life Stage/Size Stocked	Time from Release	Recapture Rate (% of number stocked)	Reference
River Tweed (Scotland)	10 inches	5 months	41.2%	Mills and Ryan (1973)
Mill River (North Carolina)	5-7"	~8-9 months	10.0%	Holloway and Chamberlain (1942)
		~20-21 months	10.6%	
		~32-33 months	4.8%	
	7-9"	~3 months	1.1%	
		~15 months	14.4%	
			4.3%	
Pigeon River (Michigan)	Catchables	~8 months	6.8%	Shetter and Hazzard (1940)
		1 year	3.2%	
		~5 months	15.6%	
		~4 months	2.0%	
Pigeon River (Michigan)	Catchables	40 days	26.0%	Cooper (1952)
Sucker and Splitrock Rivers (Minnesota)	Adults	~5 months	10%	Hale (1952_b)
Sydenham River (Ontario)	Yearlings	1 year	8.1%	Millard (1971)